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DRAFT

Baseline Risk Assessment

Part 2—GROUNDWATER

Reynolds Metals Company
TROUTDALE FACILITY

CH2MHILL

JULY 1999

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Abbreviations and Acronyms

AOC	Administrative Order on Consent
ARARs	applicable or relevant and appropriate requirements
atm-m^3/mole	atmosphere-cubic meter per mole
AWQC	ambient water quality criteria
bgs	below the ground surface
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COE	U.S. Army Corps of Engineers
COPC	chemical of potential concern
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
DEQ	Oregon Department of Environmental Quality
DI	daily intake
ECAO	[EPA] Environmental Criteria and Assessments Office
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
FF	Flood Fringe
FS	feasibility study
gpm	gallons per minute
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HM	Urban Heavy Manufacturing
HQ	hazard quotient
IRIS	Integrated Risk Information System
kg	kilogram
MCC	Multnomah County Code
MCL	maximum contaminant level
MCPC	Multnomah County Planning Commission
mg/kg-day	milligrams of chemical contacting the body per kilogram body weight per day
mg/L	milligrams per liter
MRL	method reporting limit
MW	monitoring well
NOAEL	no observed adverse effect level
OSWER	[EPA] Office of Solid Waste and Emergency Response
OWRD	Oregon Water Resources Department
PCE	tetrachloroethene
ppm	parts per million
PRG	preliminary remediation goal

PW	production well
RA	risk assessment
RfD	reference dose
RI/FS	remedial investigation/feasibility study
RMC	Reynolds Metals Company
RME	reasonable maximum exposure
SAP	*Sampling and Analysis Plan*
SEC	Significant Environmental Concern
UCL	upper confidence limit
UF-20	Urban Future
UGS	upper gray sand
USFWS	U.S. Fish and Wildlife Service
VOCs	volatile organic compounds

Executive Summary

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Executive Summary

This document presents the results of a human health risk assessment (HHRA) and ecological risk assessment (ERA) for groundwater at the Reynolds Metals Company (RMC) facility in Troutdale, Oregon. This evaluation was conducted in accordance with an Administrative Order on Consent issued by the U.S. Environmental Protection Agency (EPA), Region 10, and signed by RMC in September 1995.

This document is Part 2 of the baseline risk assessment (RA) for the Troutdale site. It addresses potential groundwater pathways and risk posed by possible exposure to groundwater. Part 1 of the baseline RA addressed direct contact pathways associated with soil, surface water, and sediment.

Purpose of This Report

The purpose of this RA is to estimate the realistic potential for risk to human health and ecological receptors posed by the threatened or actual release of chemicals of potential concern (COPCs) that are present in groundwater at the site in the absence of any further remedial action. This RA was conducted using standard EPA methodologies as well as additional approaches and assumptions agreed to by RMC and EPA, the Oregon Department of Environmental Quality (DEQ), and the U.S. Fish and Wildlife Service (USFWS) in a series of meetings held in 1998-99. The resulting risk estimates serve, along with other factors, as the basis of risk management decisions for the RMC-Troutdale facility.

The main objective of the HHRA is to determine whether concentrations of chemicals released to the site media result in human cancer or noncancer risks that exceed regulatory risk threshold levels. A consideration of current and reasonably anticipated future land uses provides identification of the most feasible human exposure pathways for RMC-Troutdale. This HHRA was conducted using a tiered framework, intended to prioritize and focus the results on information most critical for risk management decisions regarding groundwater at the site. The analysis of human health risks uses chemical data generated during the remedial investigation (RI) and a variety of standard and site-specific exposure assumptions.

Human Health Risk Assessment Findings

The HHRA for groundwater was conducted in three steps:

- **Identification of COPCs** – Identification of those constituents in groundwater that are of most interest for risk quantification
- **Tier 1 HHRA** – Further prioritization of COPCs to be addressed during Tier 2
- **Tier 2 HHRA** – Identification of potential risks posed at the most relevant current and future exposure points onsite and offsite

The results of these three steps are described below.

Chemicals of Potential Concern Selection Process

COPCs are those chemicals that are to be carried through the human health risk quantification process. To identify COPCs, groundwater analytical results were evaluated from all monitoring wells (MWs) and production wells (PWs) installed within the boundaries of the Troutdale site, regardless of location or what hydrogeologic zone the well was screened in. Groundwater data were selected for evaluation from the four most recent sampling events for each individual well to provide the best representation of current conditions. Any chemical that was detected in groundwater at least once during this period was evaluated to determine whether it should be identified as a COPC for the HHRA. The maximum concentration of each chemical detected in sitewide groundwater was compared with risk-based screening levels. If the maximum chemical concentration in groundwater anywhere onsite exceeded a target cancer risk of 1×10^{-6} or a noncancer hazard quotient (HQ) of 0.1, it was considered a COPC and carried forward into the Tier 1 RA. The maximum concentrations for 18 of the 38 chemicals detected in groundwater exceeded the risk-based screening values. Therefore, 18 chemicals were selected as COPCs and carried forward into the Tier 1 RA.

Tier 1 Human Health Risk Assessment

The purpose of the Tier 1 HHRA was to identify which of the 18 selected COPCs present in sitewide groundwater (at any location or hydrogeologic zone) exist at concentrations that could feasibly pose risk at relevant exposure points (that is, where drinking wells are currently placed or could reasonably be placed in the future), and should be carried into Tier 2.

Chemical intakes and risk estimates were calculated during Tier 1 for each individual well at the site. The Tier 1 exposure point concentrations (EPCs) were estimated using direct chemical measurements in groundwater from well locations with measurable COPC concentrations. The maximum detect of each COPC from the four most current rounds of data was used for the well-specific evaluation. Following the well-specific analysis, any chemicals in any individual sitewide monitoring well with concentrations exceeding an excess lifetime cancer risk of 1×10^{-6} or a hazard quotient of 1.0 were selected to be carried forward into the Tier 2 HHRA.

Although the occupational worker is the most likely future receptor at RMC-Troutdale, the results obtained assuming residential exposure were used during Tier 1 to identify constituents to address in the Tier 2 HHRA, as recommended by EPA. The results of Tier 1 indicated that, of the 18 sitewide COPCs identified for groundwater, the following eight constituents exist at maximum concentrations that could feasibly pose risk at relevant exposure points and were carried forward into the Tier 2 HHRA:

- 1,1-Dichloroethene (1,1-DCE)
- 1,2-Dichloroethane (1,2-DCA)
- Arsenic
- Cyanide
- Fluoride

- Iron
- Manganese
- Tetrachloroethene (PCE)

Tier 2 Human Health Risk Assessment

The Tier 2 HHRA uses site-specific information to provide more realistic exposure estimates for the most important COPCs identified in Tier 1. The exposure settings and exposure points evaluated (described below) were selected on the basis of discussions with EPA and DEQ during the RI, and are consistent with current and reasonably anticipated future land uses.

As discussed in the conceptual exposure model (Section 2), workers are the most likely receptor for groundwater use, both onsite at RMC-Troutdale and offsite at Sundial Marine Tug & Barge and Gresham Sand & Gravel, under both current and future land use conditions. Residents are also considered potential receptors under future offsite land use conditions. For all exposure settings, potential health risks from chemical concentrations in groundwater were evaluated for ingestion, dermal contact, and inhalation [volatile organic compounds (VOCs) only] routes of potential exposure.

Exposure Settings Considered for Tier 2

Four exposure settings were evaluated during Tier 2 to reflect current and future conditions both onsite and offsite. The potential exposure settings considered for the groundwater HHRA include:

- **Current Onsite Occupational Use.** Potential current occupational exposure to chemicals in main plant area groundwater by ingestion and by dermal contact during showering.[1]
- **Current Offsite Occupational Use.** Potential current offsite occupational exposure to chemicals in downgradient groundwater (Sundial Marine Tug & Barge and Gresham Sand & Gravel) by ingestion and by dermal contact during showering.[1]
- **Future Onsite Occupational Use.** Potential future occupational exposure to chemicals in main plant area groundwater by ingestion and by dermal contact and inhalation of VOCs during showering.
- **Future Offsite Occupational and Residential Use.** Potential future occupational or residential exposure to chemicals in downgradient groundwater by ingestion and by dermal contact during showering.[1]

Exposure Points Considered for Tier 2

For the subset of groundwater COPCs identified during Tier 1 to be carried forward into the Tier 2 HHRA, EPCs were estimated at the most relevant exposure points at or near the RMC facility. The most relevant exposure points for onsite and offsite groundwater were identified as locations where human use of groundwater is currently occurring, or where future well placements are most feasible. Feasible well placement locations were selected on the

[1] Inhalation of VOCs during showering is not a complete exposure pathway for current or future offsite or current onsite exposure settings.

basis of consideration of reasonably anticipated future land use, groundwater flow direction, current groundwater concentration data, and review of the results of the regional well survey [Section 3 of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, 1999b)].

For future settings (both onsite and offsite), exposure points were located where the highest potential for exposure to COPCs could occur. The exposure points evaluated were agreed to in discussions with EPA and DEQ during the 1999 monthly meetings. These exposure points are as follows:

- **Current Onsite Exposure Point.** At the drinking water tap currently supplying production well water to the RMC facility.
- **Future Onsite Exposure Point.** At well PW08, which contains higher concentrations of fluoride than are observed in tap water or other individual production wells at the RMC facility.
- **Current Offsite Exposure Point.** At the drinking water tap supplying well water at Sundial Marine Tug & Barge and Gresham Sand & Gravel. These are identified as the only currently active wells downgradient of RMC.
- **Future Offsite Exposure Point.** At a hypothetical well located in the northeast corner of Fairview Farms, representing high-end concentrations of fluoride in offsite groundwater downgradient of the RMC facility.

EPCs at each of these exposure points were estimated using either directly measured groundwater concentrations at the wells specified or concentrations modeled spatially and temporally, as described in Section 3.4.5.2.

Tier 2 Results

The results of the Tier 2 risk estimates for the four groundwater exposure settings identified for RMC-Troutdale are provided in Table ES-1. The cancer and noncancer risk estimates for onsite and offsite exposure points, under current and future site conditions, are summarized. The results are listed by exposure route, as well as the total multi-route risk estimates. The individual risk calculation data sheets used to develop the risk summary table for each exposure setting described below are provided in Appendix E.

As part of the groundwater risk evaluation, the resulting risk estimates are compared with EPA target risk criteria. Because DEQ target risk criteria are considered applicable or relevant and appropriate requirements (ARARs) for the remedial investigation/feasibility study (RI/FS), a comparison is also made with these criteria. An exceedance of regulatory risk criteria indicates that a particular pathway should be addressed during the feasibility study. The EPA and DEQ target risk criteria are as follows:

- For EPA, target risk levels are exceeded when the total (multichemical) excess lifetime cancer risk exceeds 1×10^{-4} or the total noncancer hazard index exceeds 1.0 (EPA, 1991b).
- For DEQ, target risk levels are exceeded when the total (multichemical) excess lifetime cancer risk exceeds 1×10^{-5} (or 1×10^{-6} for a single carcinogen) or the total noncancer hazard index exceeds 1.0 (Oregon Administrative Rule 340-122). For chemicals with

available drinking water maximum contaminant levels (MCLs), the MCL is considered the DEQ target limit in place of the risk-based limit and applies at relevant exposure points.

The results of Tier 2 indicate that, of the four exposure settings evaluated, the future offsite residential water use setting results in noncancer risks exceeding EPA's risk level of a hazard quotient greater than 1.0. The estimated future offsite fluoride concentrations also exceed DEQ's target, the MCL of 4 milligrams per liter (mg/L). All other exposure settings result in risk estimates below regulatory limits. These results are considered during the evaluation of remedial alternatives for groundwater as part of the feasibility study (FS) for RMC.

Table ES-1
Summary of Tier 2 Risk Estimates for Current and Future Exposure to Groundwater

Exposure Scenario	Exposure Route	Average Exposure		Reasonable Maximum Exposure	
		Noncancer Hazard Index	Excess Lifetime Cancer Risk	Noncancer Hazard Index	Excess Lifetime Cancer Risk
Current Onsite Occupational Worker	Ingestion	N/C	N/C	0.26	N/A
	Dermal	N/C	N/C	0.001	N/A
	Inhalation	N/C	N/C	N/A	N/A
	Total	N/C	N/C	0.26	N/A
Future Onsite Occupational Worker	Ingestion	N/C	N/C	0.34	9×10^{-7}
	Dermal	N/C	N/C	0.002	2×10^{-7}
	Inhalation	N/C	N/C	N/A	5×10^{-6}
	Total	N/C	N/C	0.34	6×10^{-6}
Current Offsite Occupational Worker	Ingestion	N/C	N/C	0.057	N/A
	Dermal	N/C	N/C	0.0003	N/A
	Inhalation	N/C	N/C	N/A	N/A
	Total	N/C	N/C	0.06	N/A
Future Offsite Occupational Worker	Ingestion	N/C	N/C	0.95	N/A
	Dermal	N/C	N/C	0.004	N/A
	Inhalation	N/C	N/C	N/A	N/A
	Total	N/C	N/C	0.95	N/A
Future Offsite Residential	Ingestion	1.8	N/C	3.2	N/A
	Dermal	0.004	N/C	0.007	N/A
	Inhalation	N/A	N/C	N/A	N/A
	Total	**1.8**	N/C	**3.3**	N/A

N/C = Not calculated; the average-case risk estimates were calculated only when the RME case estimates exceeded EPA target risk levels [$>10^{-4}$ excess lifetime cancer risk (ELCR); > 1.0 hazard index (HI)].
N/A = Exposure is incomplete for this exposure route.

Ecological Risk Assessment Findings

The only feasible pathway by which site-related constituents in groundwater could reach ecological receptors is discharge to the Columbia and Sandy Rivers. This Part 2 of the baseline risk assessment addresses potential ecological risks posed only by groundwater. The potential ecological risks posed by constituents directly measured in surface water and sediment collected during the RI were evaluated in Part 1 of the baseline RA.

The primary ecological assessment endpoint selected for the rivers is survival and health of fingerling stages of anadromous and resident fish. Of the constituents detected in groundwater, fluoride was determined the most important site-related constituent. To assess the potential exposure concentrations in the rivers, calculations were conducted to estimate the amount of mixing that occurs in each river and the resulting fluoride concentrations. The objective of the calculations was to conservatively estimate the feasible in-stream concentrations in the two rivers so that ecological risk could be evaluated. The magnitude of mixing between groundwater and surface water was calculated as a mixing factor that is a ratio of the sum of groundwater and surface water flows divided by the groundwater flow. This mixing factor was then used with the groundwater fluoride concentrations (measured at the temporary Geoprobe® locations along the rivers) to estimate the potential in-stream exposure concentration of fluoride.

To provide a range of river flow conditions, mixing-factor calculations were performed for the following three separate river flow rates:

- The 7Q10 flow (7-day sustained low flow expected to occur once every 10 years)
- The minimum monthly low flow
- The mean annual flow

In addition, these calculations were performed for three separate assumed percentages of total river flow available for mixing. The selected percentages for each river were based on the minimum estimated cross-sectional riverbed area for groundwater discharge, the maximum estimated area for groundwater discharge, and an intermediate area.

The mixing calculations for the Columbia River indicated that, even under the most conservative river flow conditions (7Q10), the mixing factor ranges between about 34,000 and 84,000 (CH2M HILL, 1998a). The mixing calculations for the Sandy River indicated that, under the most conservative flow conditions (7Q10), the mixing factor ranges from about 90 to 450. The mixing factors increase for higher river flow rates and higher percentages of the river flow that are available for mixing.

On the basis of the calculated in-stream fluoride concentrations and available toxicity values, no adverse effect is expected to aquatic organisms under any of the most plausible streamflow conditions. An additional comparison of nonfluoride estimated exposure concentrations with freshwater toxicity benchmarks indicated that all the estimated concentrations are expected to be well below the benchmarks. Therefore, they are expected to be well below levels that could adversely affect aquatic organisms.

SECTION 1

Introduction

SECTION 1

Introduction

This document presents Part 2 of the baseline risk assessment (RA) for the Reynolds Metals Company (RMC) facility at Troutdale, Oregon (see Figure 1-1). Part 1 of the baseline RA (CH2M HILL, 1999a) addressed direct contact pathways associated with soil, surface water, sediment, and biota for both human health and ecological risk. Part 2 addresses potential groundwater pathways and risk posed by possible exposure to groundwater.

This document, Part 2, contains the following sections:

- Section 1 describes the project background, the management approach, supporting documents completed to date, and the overall purpose and approach for the baseline RA
- Section 2 presents the conceptual site model based on a current understanding of the RMC facility and surrounding area
- Section 3 is the baseline human health risk assessment (HHRA)
- Section 4 summarizes an evaluation of the potential ecological pathways associated with groundwater

1.1 Background

This baseline RA is part of the remedial investigation/feasibility study (RI/FS) being conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Administrative Order on Consent (AOC) issued by the U.S. Environmental Protection Agency (EPA), Region 10, and signed by RMC in September 1995.

1.1.1 Management Approach to RI/FS

The management approach to the RI/FS has been to divide the site issues into the following categories for evaluation of risk and potential remedial action:

- Sitewide groundwater
- Soil and debris areas
- Wastewater discharge areas
- Surface water and sediment areas

Part 2 of the baseline RA addresses the risk associated with exposure to sitewide groundwater. Figure 1-2 shows the locations of monitoring wells and production wells installed at RMC-Troutdale. The risks associated with nongroundwater media in the soil and debris areas, the wastewater discharge areas, and the surface water and sediment areas were presented as Part 1 of the baseline RA (CH2M HILL, 1999a). These areas are shown in Figure 1-2 of that document.

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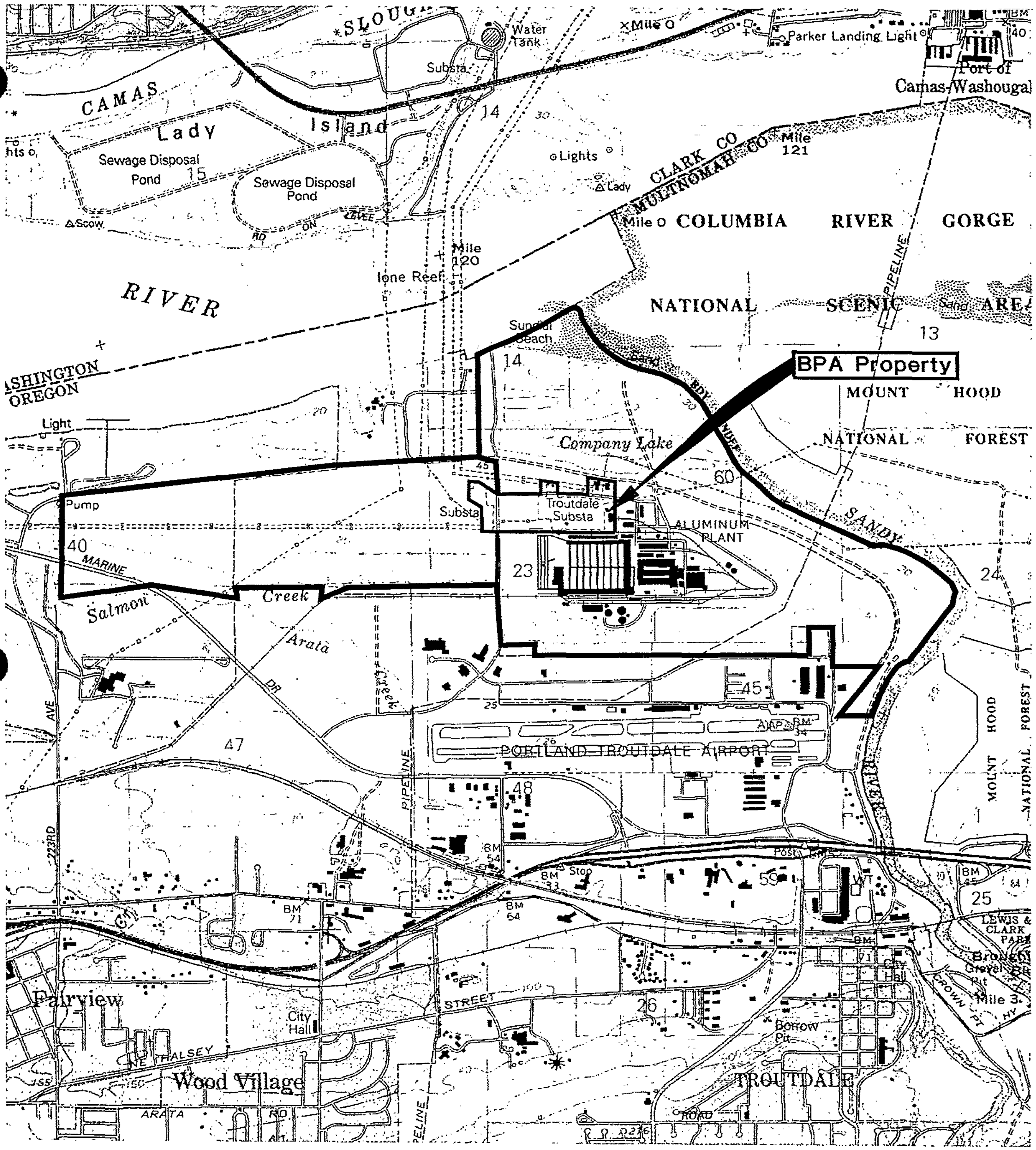

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SCALE IN FEET

LEGEND

APPROXIMATE PROPERTY BOUNDARY

Figure 1-1
VICINITY MAP
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2–Groundwater

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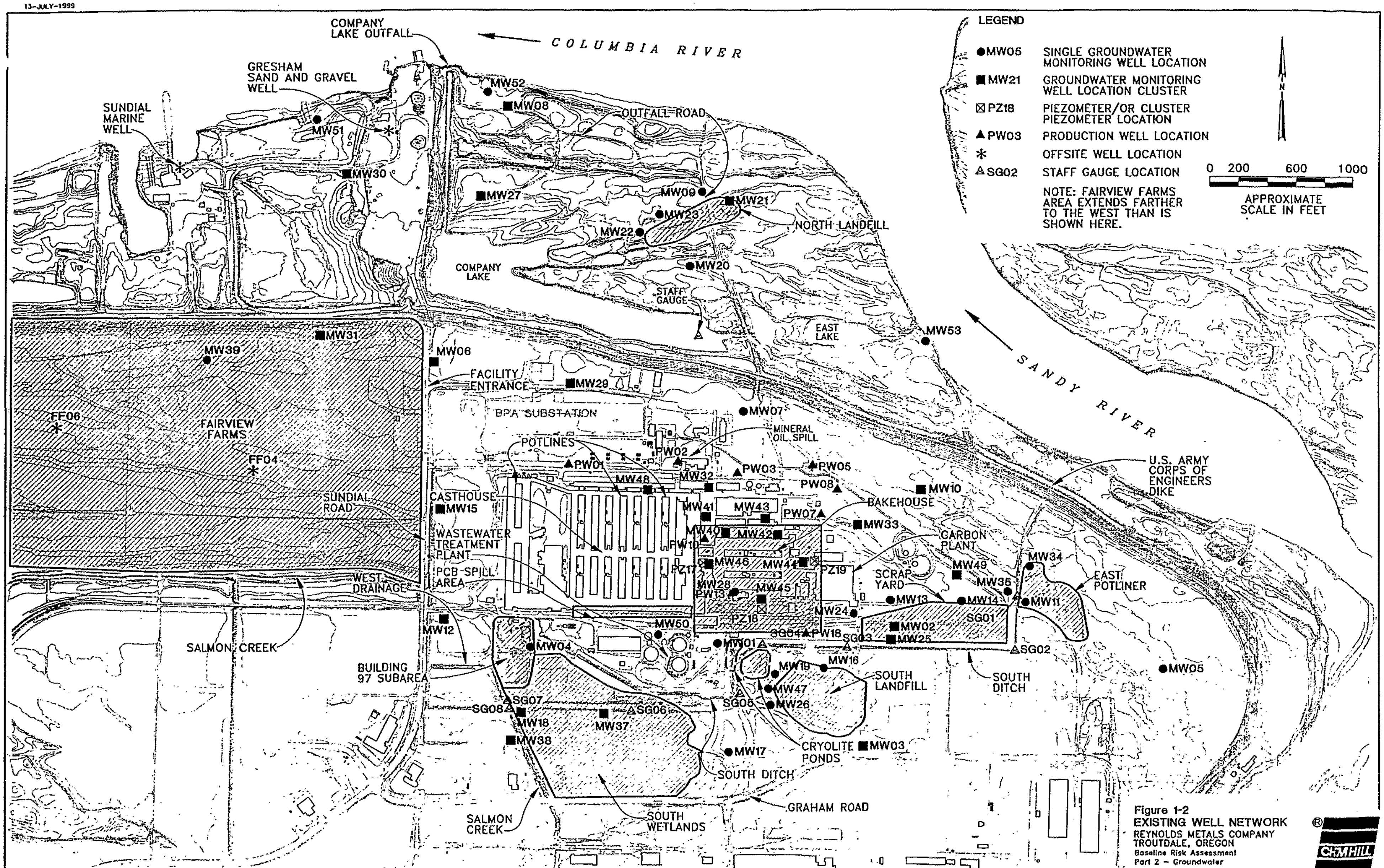


Figure 1-2
EXISTING WELL NETWORK
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2 – Groundwater

It is important to note that one of the primary purposes of the early actions taken to date (for example, soil removals at the east potliner area) was to reduce potential contributions from migration of constituents from soil to groundwater. Because some of these early actions have been relatively recent, this baseline RA may incorporate groundwater concentrations that do not yet fully reflect the effect of these actions.

1.1.2 Preceding Documentation

RMC submitted the *Draft Remedial Investigation/Feasibility Study Work Plan* (Work Plan) on May 8, 1996. The Work Plan presented the rationale, strategy, and approach for the overall investigation, leaving the details of the investigation to a series of addenda to the Work Plan that were developed and submitted during the next 2 years. These addenda and their submittal dates are:

- *Draft South Wetlands Addendum to the RI/FS Work Plan* (CH2M HILL, May 8, 1996)
- *Draft Human Health and Ecological Risk Assessment Addendum to the RI/FS Work Plan* (CH2M HILL, August 5, 1996)
- *Draft Soil and Debris Areas Addendum to the RI/FS Work Plan* (CH2M HILL, February 18, 1997)
- *Draft Groundwater Addendum to the RI/FS Work Plan* (CH2M HILL, June 2, 1997)
- *Wastewater Discharge Areas Addendum to the RI/FS Work Plan* (CH2M HILL, December 1997)
- *Draft Surface Water and Sediment Areas Addendum to the RI/FS Work Plan* (CH2M HILL, April 3, 1998)

Each of these addenda (except groundwater[1]) presented a preliminary assessment of risk based on the data available at that time and identified additional data required to complete the baseline RA. Following collection of the additional data, the following documents presented data results and, where possible, updated the preliminary risk evaluation for the areas addressed:

- *Technical Memorandum DS No. 16: Data Summary for the Soil and Debris Areas Addendum to the RI/FS Work Plan – 1997 Sampling at North Landfill, South Landfill, and Scrap Yard* (CH2M HILL, December 15, 1997)
- *Technical Memorandum DS No. 17: Data Summary for the Wastewater Discharge Areas Addendum to the RI/FS Work Plan, Part 1* (CH2M HILL, December 12, 1997)
- *Technical Memorandum DS No. 18: Data Summary for the Wastewater Discharge Areas Addendum to the RI/FS Work Plan, Part 2* (CH2M HILL, June 17, 1998)

[1] For groundwater, sampling and analysis have been conducted quarterly since mid-1994 through 1998 (semiannually in 1999), and the results have been reported as they became available. However, none of the preceding data presentations for groundwater included risk assessment evaluations.

- *Technical Memorandum DS No. 14: Data Summary for the South Wetlands Addendum to the RI/FS Work Plan, Part 1 – Soil, Surface Water, and Groundwater Quality* (CH2M HILL, February 12, 1997) [The information originally planned for Part 2 is presented in Appendix A of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, June 1999]

1.1.3 Supporting Documentation

Several documents addressing groundwater beneath the Troutdale site have been prepared; they contain site information and groundwater modeling data required to complete the groundwater baseline RA. These documents and their submittal dates are as follows:

- *Draft Groundwater Remedial Investigation Report* (CH2M HILL, June 1999)
- *Technical Memorandum No. GW-20: Development of an Updated Hydrogeologic Conceptual Model and a Numerical Groundwater Flow Model at RMC-Troutdale* (CH2M HILL, June 25, 1999)
- *Draft Baseline Risk Assessment, Part 1—Nongroundwater Media* (CH2M HILL, May 1999)

The baseline RA presented in this document builds on this preceding work.

1.2 Purpose of the Risk Assessment

The overall vision for this RA is to provide estimates of site risk that:

- Realistically reflect actual site conditions
- Provide a basis for making informed decisions
- Are communicated in an understandable manner

The objective of this baseline RA is to determine the nature, magnitude, and probability of actual or potential harm to human health, safety, or welfare, or to the environment posed by the threatened or actual release of hazardous substances at or from the Troutdale site in the absence of any further remedial action. The baseline RA identifies and characterizes the toxicity of the chemicals of potential concern (COPCs), potential exposure pathways, potential human and environmental receptors, and the likelihood and extent of impact or threat under the conditions defined for the site.

The results of this baseline RA will be useful in deciding whether a current or potential future risk to human health or the environment exists that warrants remedial action at the site. If remedial action is required, additional risk assessments may be conducted for comparison of remedial alternatives to identify potential threats to human health or the environment that might arise from the execution of various remediation activities. Finally, the risk assessment process provides a basis for determining concentrations of chemicals that can remain in the environment and still be adequately protective of human health and the environment.

1.3 Overview of the Risk Assessment Process for RMC-Troutdale

The overall risk assessment process for the Troutdale site is shown in Figure 1-3. The process is divided into four phases:

- Preliminary risk evaluation to identify data needs
- Collection of additional data to support the HHRA and the ecological risk assessment (ERA)
- Development of consensus approaches for the baseline RA
- The baseline HHRA and ERA

The first phase, the preliminary risk evaluation, identified data representativeness, data quality, and data needs for the soil and debris areas, the wastewater discharge areas, and the surface water and sediment areas. These preliminary risk estimates were presented in the appropriate Work Plan addendum. Sitewide groundwater investigations have been ongoing, and no preliminary risk evaluation has previously been conducted.

During phase two, additional groundwater data were collected, allowing development of a hydrogeologic conceptual model and a numerical groundwater flow model for the Troutdale facility (CH2M HILL, 1999c). The numerical flow model was constructed to estimate potential exposure point concentrations in support of this groundwater baseline RA. It also serves as a tool to evaluate the effectiveness of various groundwater remedial alternatives for the multi-layer aquifer underlying the site, including the degree of risk reduction that would occur under various groundwater remedial alternatives.

In the third phase, a series of monthly meetings between RMC and EPA, the Oregon Department of Environmental Quality (DEQ), and the U.S. Fish and Wildlife Service (USFWS) were held during 1998-99 to develop consensus on risk assessment methodologies, assumptions, and sampling needs. The HHRA and ERA presented in Parts 1 and 2 use these approaches and assumptions, in accordance with the agreements made.

The fourth and final phase of the overall RMC RA process is the baseline RA contained in this document. As detailed in Section 3 (HHRA), a tiered risk assessment is conducted to focus the final baseline RA on the chemicals, areas, and pathways of greatest concern for risk management at the site. The results provide input to the sitewide FS.

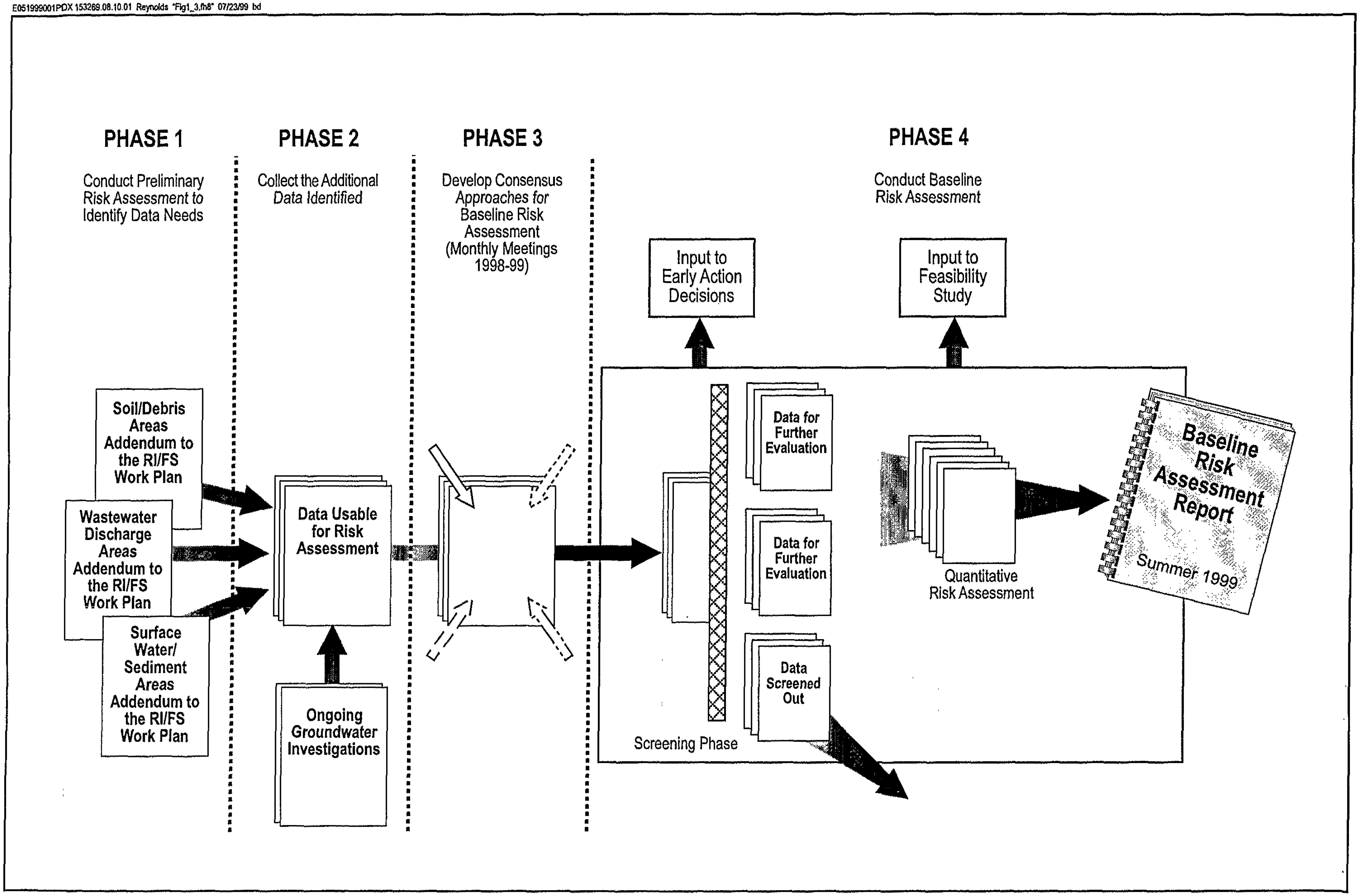


Figure 1-3

Risk Assessment Process

REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2—Groundwater

SECTION 2

Conceptual Site Model

SECTION 2

Conceptual Site Model

The conceptual site model for the Troutdale facility provides a current understanding of the sources of contamination, physical setting, current and future land use, and local groundwater use, to identify potentially complete exposure pathways for the Troutdale site. Information generated during the RI has been incorporated into this conceptual site model to identify potential exposure scenarios. This section focuses on the conceptual site model for groundwater at RMC-Troutdale. The conceptual site model for nongroundwater media has been provided in Section 2 of the Part 1 baseline RA. Section 2.1 of Part 1 summarizes the physical setting of each nongroundwater area of concern being addressed by the RI/FS at the Troutdale site, and Figure 1-2 of Part 1 shows the location of each area.

2.1 Hydrogeologic Setting

The unconsolidated sediments within the uppermost regional groundwater system beneath the site have been subdivided into four water-bearing zones. These zones, defined by the site stratigraphy and the depths at which monitoring wells have been constructed, are:

- Silt unit [ground surface to 30 feet below the ground surface (bgs)]
- Upper gray sand (UGS, 30 to 50 feet bgs)
- Intermediate sand (50 to 100 feet bgs)
- Deep sand/gravel (100 to 200 feet bgs)

Flow patterns within the silt unit are controlled primarily by infiltration and the influences of localized surface water features. Silt unit groundwater generally moves vertically into the UGS and horizontally over limited distances toward these surface water features. The horizontal hydraulic conductivity of the silt unit is approximately 1 to 2 feet per day.

The ambient groundwater flow direction in the UGS and deeper zones beneath the RMC facility is generally from the south and southeast to the north and northwest, with groundwater discharging into the Columbia and Sandy Rivers. These flow patterns, however, are strongly controlled by pumping from the RMC production wells and by surface water features. Estimated horizontal hydraulic conductivities are 2 to 35 ft/day for the UGS, 100 to 150 ft/day for the intermediate sand, and 75 to 175 ft/day for the deep sand zones.

A detailed description of the conceptual hydrogeologic model for the site is provided in Section 3 of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, 1999b).

2.2 Characterization of Land Use

Section 2.2 of the Part 1 baseline RA presents the characterization of land use for RMC-Troutdale. The current zoning and reasonably anticipated future land uses were evaluated to identify potentially exposed populations and to determine exposure patterns for the non-groundwater media. The same zoning designations (shown in Figure 2-1 of Part 1) are used in this report to identify feasible exposures to groundwater both onsite and adjacent to the site.

On the basis of land use conditions (as designated by Multnomah County) identified in Part 1, this Part 2 (groundwater) baseline RA considers exposure pathways specific to three areas of concern:

- **Main Plant Area.** The main plant area, located south and west of the U.S. Army Corps of Engineers (COE) dike, east of Sundial Road, and north of Graham Road, is currently zoned Urban Heavy Manufacturing (HM). RMC anticipates ownership and use of the main plant area for the foreseeable future. If ownership does change, however, zoning restrictions limit the property to industrial uses, consistent with surrounding properties. Main plant area wells include 37 monitoring wells screened in the shallow zone, 10 monitoring wells screened in the intermediate zone, 9 monitoring wells screened in the deep zone, and 8 production wells screened in the deep zone.
- **Fairview Farms.** Fairview Farms is a 222-acre fenced agricultural area located west of the RMC plant across Sundial Road, north of Salmon Creek, and south of the COE dike. This property is currently zoned HM and Urban Future (UF-20), with primary uses for single-family residences, agriculture, forestry, or conservation areas. Both of these zoning designations allow community service uses under the provisions of Multnomah County Code (MCC) 11.15.7005-30 as conditional use. On this property there is one monitoring well screened in the shallow zone and two screened in the intermediate zone. Two deep wells located on this property were formerly used for irrigation.
- **North of the COE Flood Control Dike.** RMC's property north of the dike is zoned UF-20, with overlays of areas of Significant Environmental Concern (SEC) and Flood Fringe (FF). The purpose of the SEC overlay is to protect, conserve, enhance, restore, and maintain significant natural and manmade features of public value, and an SEC permit is required for most activities allowed for the underlying zone designation. The FF zoning overlay applies to areas within the 100-year flood boundary, and no houses, grading, mining, excavation, or filling are allowed unless authorized by a Floodplain Development Permit from Multnomah County. On this property there are 13 monitoring wells (MWs) screened in the shallow zone, ten MWs screened in the intermediate zone (one was decommissioned June 28, 1998), and five MWs screened in the deep zone. The property north of the dike to the west of RMC, owned by Gresham Sand & Gravel, is zoned HM with an overlay of SEC.

Recently, zoning changes have been proposed for the area surrounding and including the RMC site. The Troutdale City Council has recommended to the Multnomah County Planning Commission (MCPC) that unincorporated land north of the City of Troutdale (that is, RMC, Gresham Sand & Gravel, Sundial Marine Tug & Barge Works, Inc., along with Bonneville Power Administration, Pacific Power & Light, and Portland General Electric property) be zoned General Industrial, with the exception of RMC property north of the dike, which would be zoned Open Space. Figure 2-2 of the Part 1 baseline RA shows the proposed zoning for the RMC area, distributed during recent correspondence with MCPC.

2.3 Regional Population Estimates

The potential for groundwater use in the future depends on population growth in the region. Section 2.3 in Part 1 of the baseline RA presents the regional population estimates for Troutdale and surrounding areas. The average annual population growth rate for the

Troutdale area from 1990 through 1997 was 3.0 percent (versus 1.3 percent for Multnomah County). Currently, approximately 520 workers are employed at the RMC plant.

2.4 Local Use of Groundwater

A survey of all groundwater uses within a 1-mile radius (south and west) of the Troutdale site was conducted to identify current local groundwater uses. The results of this survey are provided in Section 3 of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, 1999b). The locations of the nearby wells are depicted in Figure 2-1. The results of the survey were obtained by querying the Oregon Water Resources Department (OWRD) database, which contains information about well logs and groundwater rights.

The survey of local groundwater wells[1] identified the following uses:

- 17 domestic wells
- 7 wells listed as domestic and other uses (such as irrigation or manufacturing)
- 5 municipal wells (one temporarily abandoned)
- 3 irrigation wells
- 4 industrial wells (one temporarily abandoned)
- 1 test well

The total well depths for the 37 offsite wells within the search area range from 23 to 1,060 feet, and reported groundwater yields range from 12 to 1,500 gallons per minute (gpm). Only two active wells are potentially downgradient from RMC, including an industrial well at Sundial Marine Tug & Barge Works, Inc. (233 feet deep), and a domestic well (not used for consumption) at Gresham Sand & Gravel (127 feet deep).

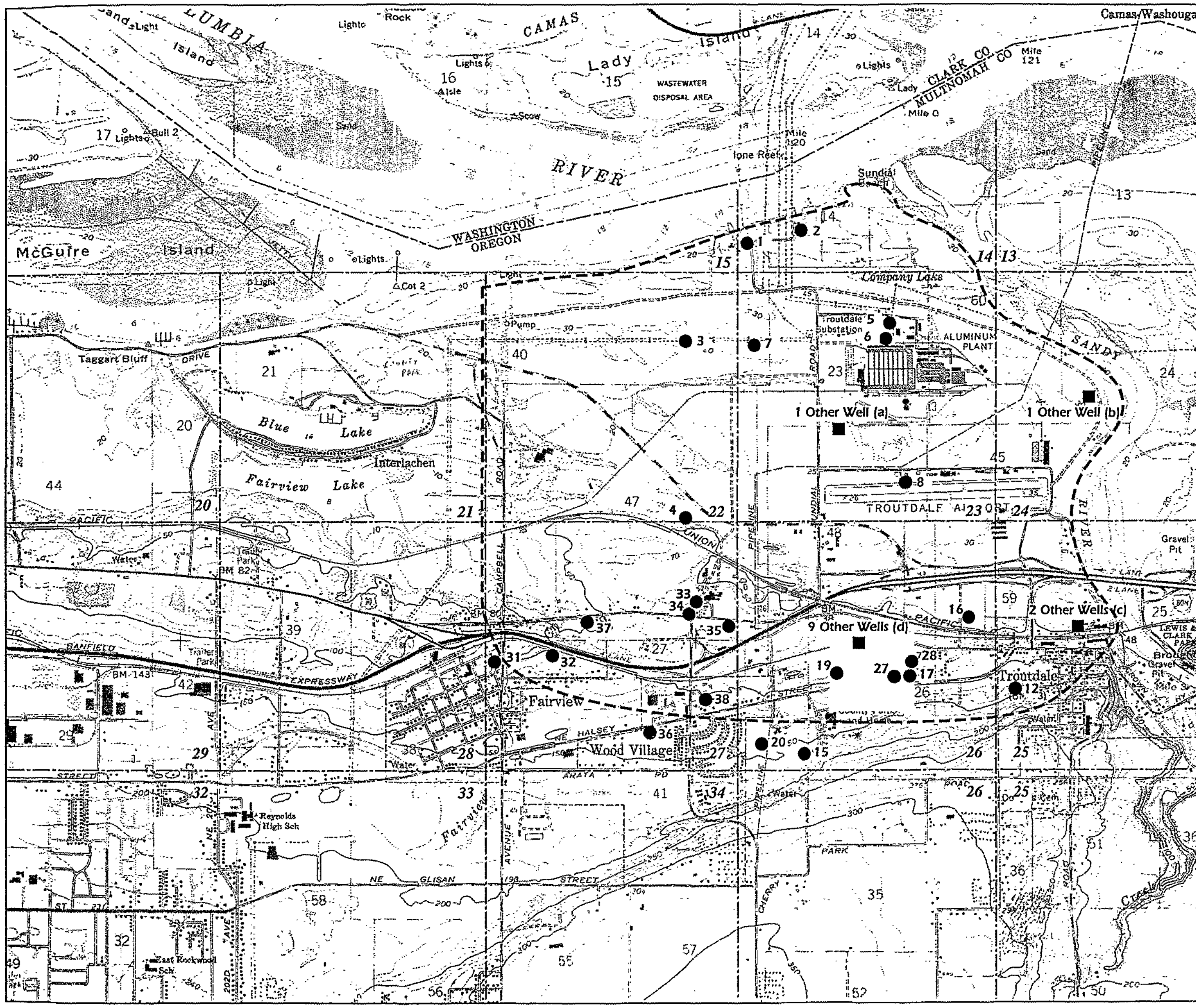
Deep groundwater beneath the RMC main plant area is currently supplied from production wells, and it is made available for consumption and other human contact (for example, showers) by RMC workers. The tap water is a composite from multiple production wells. In addition, RMC provides bottled water for use by its employees.

2.5 Conceptual Exposure Model for Human Health and Environment

An exposure pathway is the means by which a chemical moves from a source to a receptor (a potentially exposed individual or organism). A complete exposure pathway has five elements:

- A chemical source
- A mechanism for chemical release
- An environmental transport medium
- An exposure point (for example, a current or future well)
- A feasible route of exposure (for example, ingestion, dermal contact, or inhalation)

[1] Well reports were available from OWRD for 37 wells, excluding the 18 current and former production wells on the RMC property.



LEGEND

19 ● Well identified by Oregon Water Resources Department (OWRD) according to well inventory number (WIN). Water wells located within a 1-mile radius of site. Wells located to the nearest 1/4–1/4 section.

9 Other Wells ■ Number of wells in this section identified by OWRD water well reports and potentially located within 1-mile radius of site. Exact locations are unknown.

(a) WIN-9
(b) WIN-11
(c) WIN-13, WIN-14
(d) WIN-18, WIN-21, WIN-22, WIN-23, WIN-24, WIN-25, WIN-26, WIN-29, WIN-30

– – – – Approximate 1-mile radius around industrial site boundary, Columbia River to the north, and Sandy River to the east.

Notes:

1. Wells identified outside the 1-mile radius are used for hydrogeologic cross section information.
2. Rivers are assumed to be boundaries to groundwater flow. No water wells considered if located on east side of Sandy River or north side of Columbia River.

Base map: U.S. Geological Survey 7.5 minute Camas, Washington Quadrangle. Photo revised 1970 and 1975. Contour interval: 10 feet.

NORTH

0 2,000 Feet
Approximate Scale

Figure 2-1
LOCATION MAP FOR OFFSITE WATER WELLS LOCATED WITHIN A 1-MILE RADIUS OF RMC SITE
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2—Groundwater

CH2M HILL

Exposure can occur when chemicals migrate from their source to an exposure point (that is, a location where people or wildlife can come into contact with the chemicals) or when a receptor moves into direct contact with chemicals or contaminated media close to the source. An exposure pathway is complete (that is, there is a potential for exposure) if there is a means for the receptor to take in chemicals through ingestion, inhalation, or dermal absorption at a location where site-related chemicals are present. No exposure (and therefore no risk) exists unless the exposure pathway is complete. This is an important requirement in the risk assessment process.

Figures 2-2 and 2-3 present the conceptual sitewide exposure models for potential human and ecological exposures, respectively, at the Troutdale site. Similar models are presented in Appendix A (Figures A-1 through A-5) for each specific area of concern and medium, based on a current understanding of the chemical sources, release mechanisms, and routes of migration that might exist. Schematic representations of the conceptual exposure models for potential current and future human exposures, both onsite and offsite, are presented in Figures 2-4 and 2-5, respectively. The conceptual site exposure models have been formulated according to guidance using professional judgment and information on chemical sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential population groups associated with the Troutdale site.

2.5.1 Potential Human Exposure Settings

On the basis of the current understanding of land and groundwater use conditions at and near the site, as represented by Figures 2-2 and 2-3, the most plausible exposure settings that are considered for characterizing human health risks are the following:

Current Onsite Occupational Use. Potential current occupational exposure to chemicals in main plant area groundwater by ingestion and dermal contact.

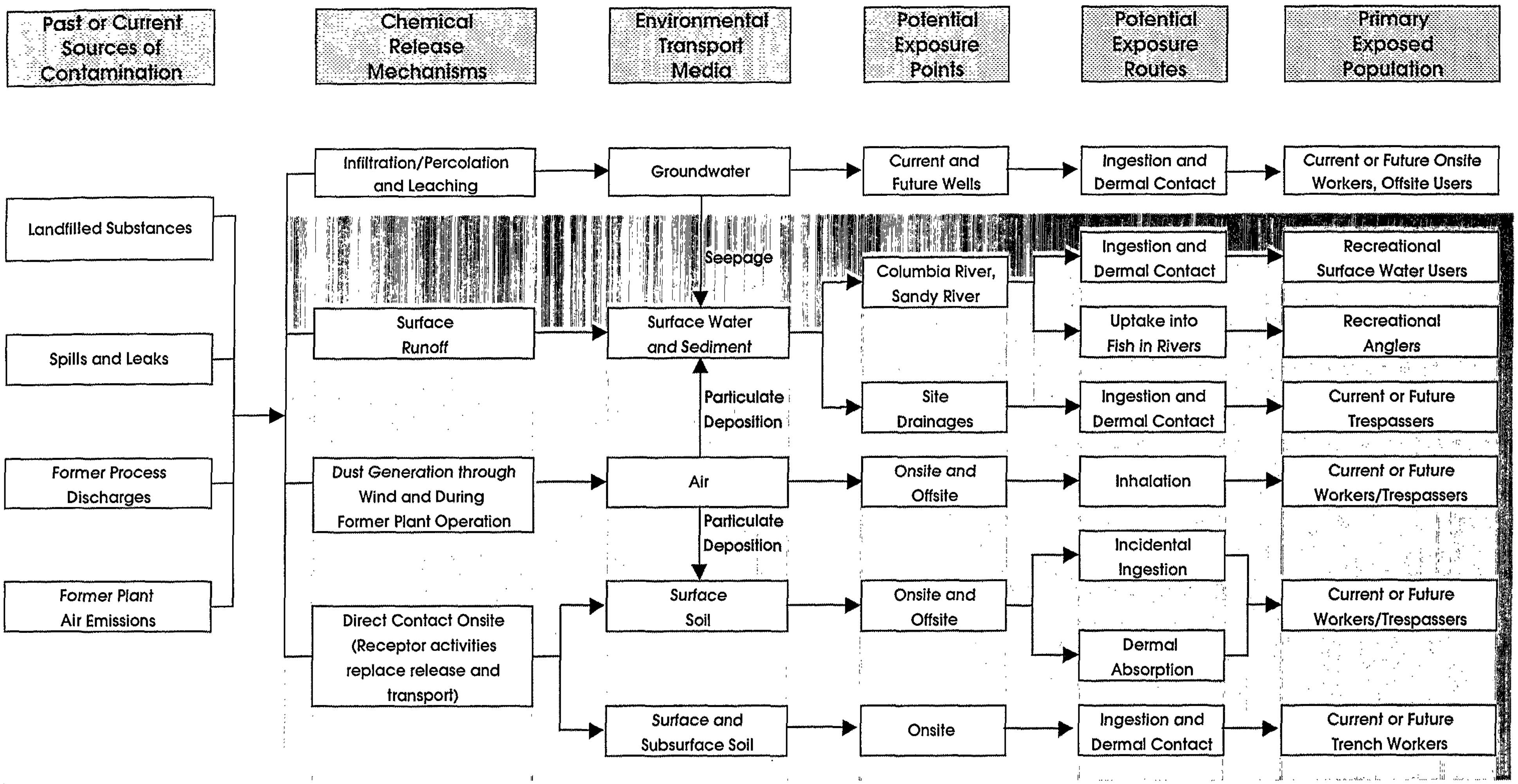
Current Offsite Occupational Use. Potential current offsite occupational exposure to chemicals in downgradient groundwater (Sundial Marine Tug & Barge Works, Inc., and Gresham Sand & Gravel) through ingestion and dermal contact.

Future Onsite Occupational Use. Potential future occupational exposure to chemicals in main plant area groundwater by ingestion, dermal contact, and inhalation of volatile organic compounds during showering.

Future Offsite Occupational and Residential Use. Potential future occupational or residential exposure to chemicals in downgradient groundwater by ingestion and dermal contact.

Discharge of Groundwater to Adjacent Surface Water Bodies. Potential current and future exposure of recreational users and ecological receptors to chemicals in groundwater discharging to surface water in the Columbia and Sandy Rivers.

Part 2 of the baseline RA focuses on the potential exposure from the first four exposure settings described above. Part 1 of the baseline RA addresses the potential human and ecological risks posed by constituents detected in surface water and sediment from adjacent surface water bodies that receive groundwater from the site. A further evaluation of the potential ecological exposures and risks from constituents detected in groundwater discharging from beneath the site is summarized in Section 4 of this Part 2 baseline RA.

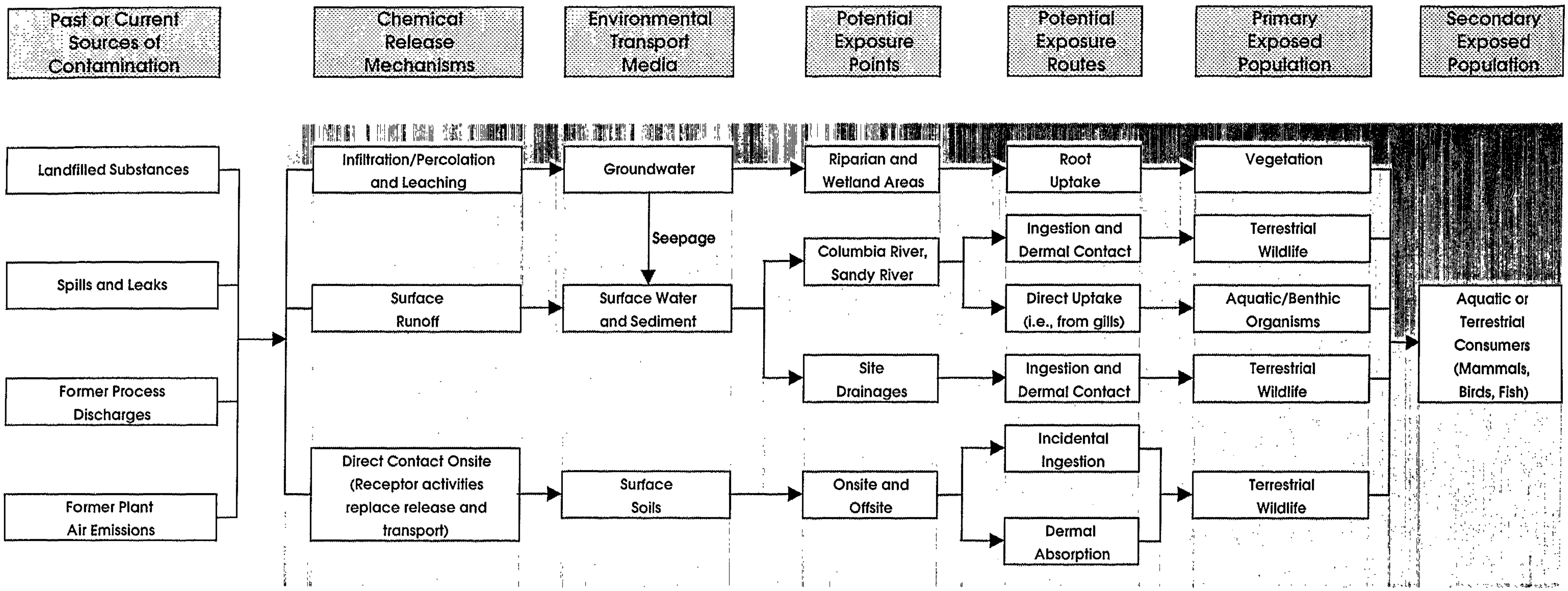


Legend:

Pathways addressed in Part 1 of Baseline RA

Figure 2-2
Sitewide Conceptual Model for Potential Human Exposures
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2--Groundwater

PDX18330.XLS



Legend:
Pathways addressed in Part 1 of Baseline RA

Figure 2-3
Sitewide Conceptual Model for Potential Ecological Exposures
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2--Groundwater

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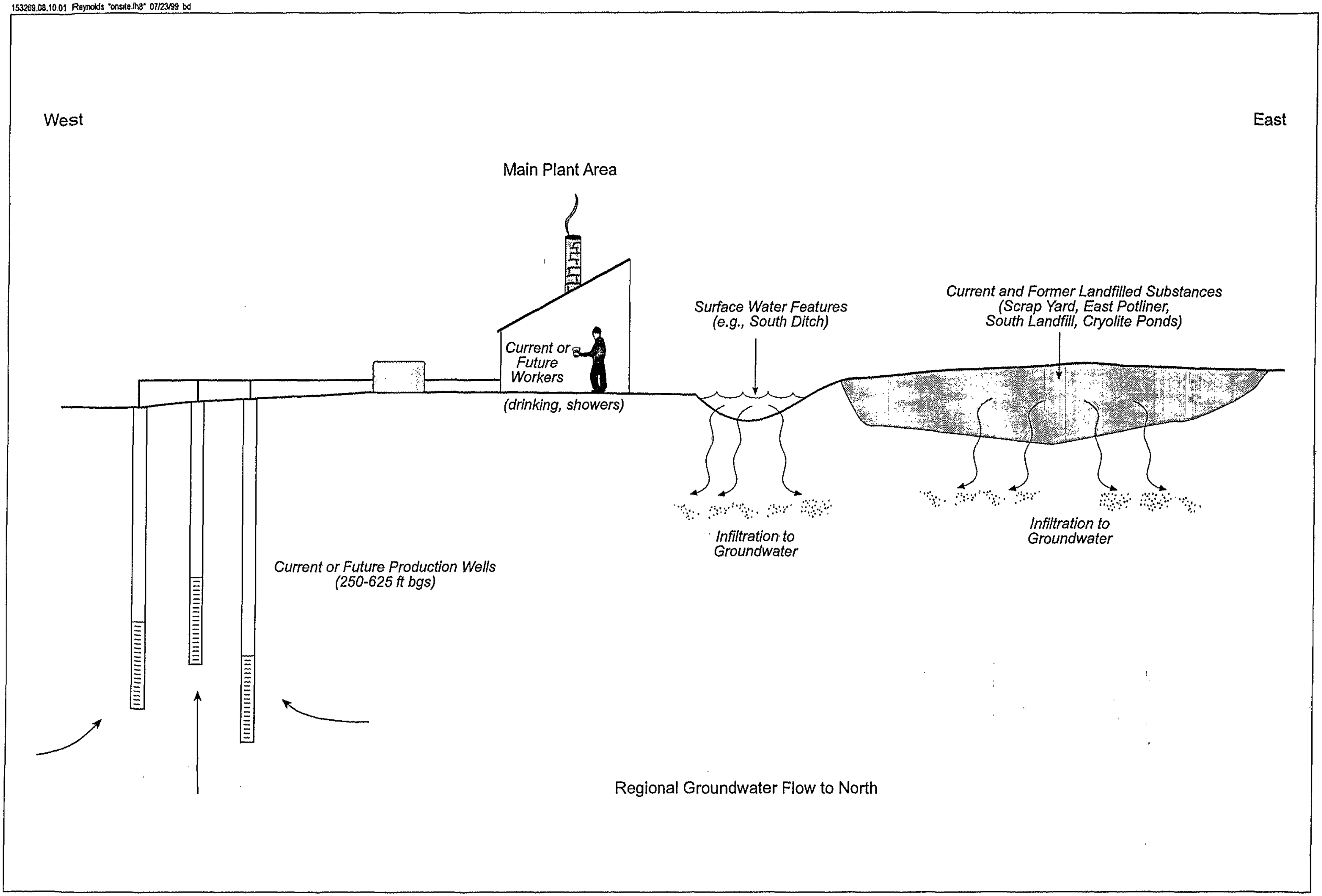

Figure 2-4
Onsite Groundwater Conceptual Exposure Schematic
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2—Groundwater

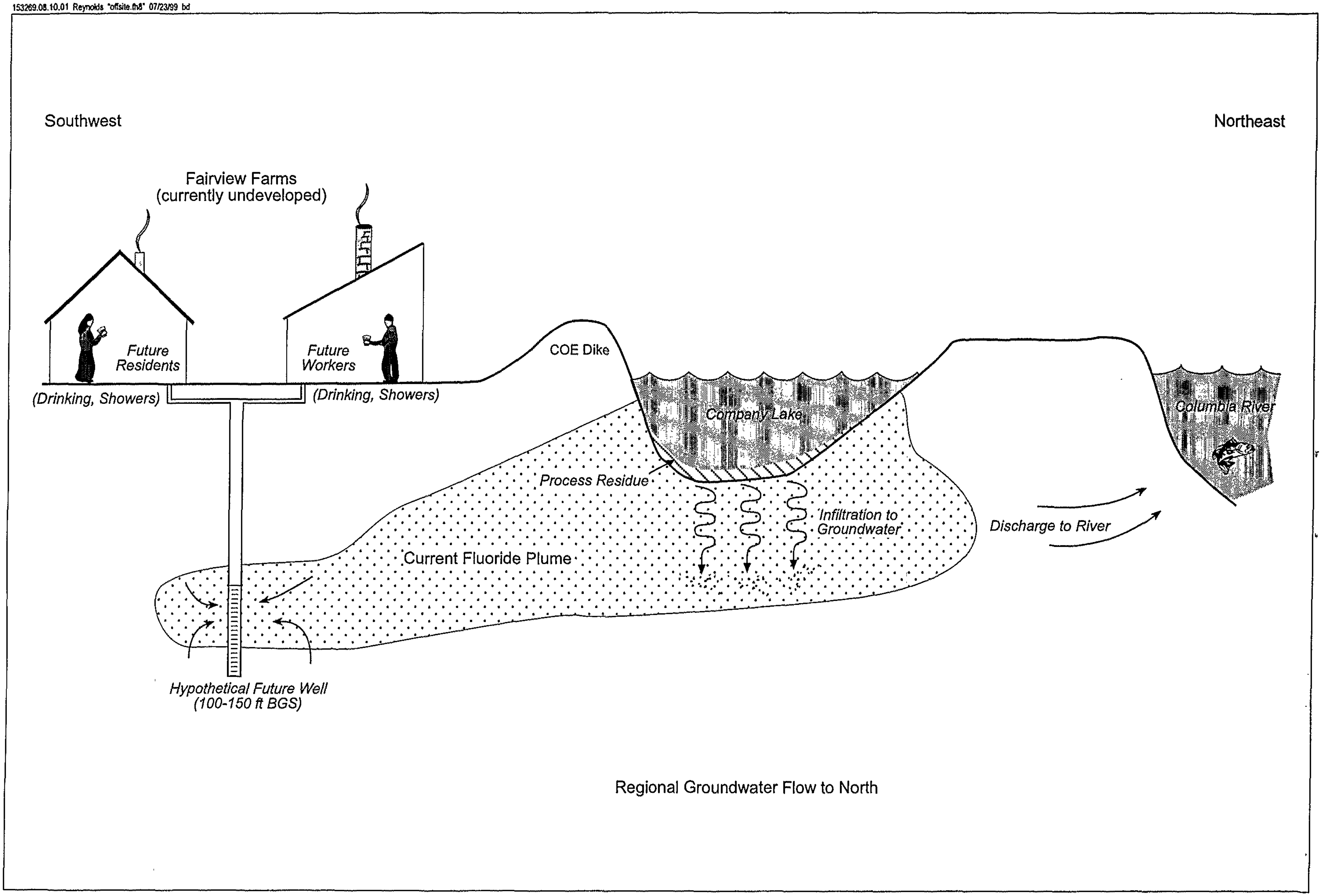

Figure 2-5
Offsite Groundwater Conceptual Exposure Schematic
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2—Groundwater

SECTION 3

Human Health Risk Assessment

SECTION 3
Human Health Risk Assessment

3.1 Organization of This Section

The baseline groundwater HHRA for the Troutdale facility is composed of the following components:

- **Human Health Risk Assessment Guidance.** Lists the guidance documents used for the HHRA.
- **Chemicals of Potential Concern for Human Health.** Identifies the constituents considered to be most important to the human health risk quantification process.
- **Human Exposure Assessment.** Identifies the pathways by which potential human exposures could occur, describes how they are evaluated, and evaluates the magnitude, frequency, and duration of these exposures.
- **Toxicity Assessment for Human Health.** Summarizes the toxicity of the selected chemicals and the relationship between magnitude of exposure and the occurrence of adverse health effects.
- **Human Health Risk Characterization.** Integrates information from the exposure and toxicity assessments to characterize the Tier 1 and Tier 2 risks to human health from potential exposure to chemicals in environmental media.
- **Identification of Major Uncertainties and Assumptions.** Summarizes the basic assumptions used in the HHRA, as well as limitations of data and methodology.

This HHRA was conducted using a tiered framework, intended to prioritize and focus the results on information most critical for risk management decisions for groundwater at the site. This approach focuses the HHRA on the chemicals, receptors, areas of concern, and hydrogeologic zones where the greatest potential for human health risk would be expected. The resulting characterization of potential risk provides sufficient information to support informed risk-management decisions at RMC-Troutdale.

The Tier 1 RA consists of a health-conservative, well-specific RA that serves to identify which of the COPCs present in sitewide groundwater (at any location or hydrogeologic zone) exist at concentrations that could feasibly pose risk at relevant exposure points (that is, where drinking wells are currently placed or could reasonably be placed in the future) and should be carried forward into Tier 2. The Tier 2 HHRA identifies potential risks posed at the most relevant current and future exposure points onsite and offsite.

3.2 Human Health Risk Assessment Guidance

The procedures used for the HHRA are consistent with those described in the following EPA guidance documents:

- *Risk Assessment Guidance for Superfund—Volume I: Human Health Evaluation Manual, Part A (Interim Final) (RAGS). EPA/540-1-89/002* (EPA, 1989)
- *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (EPA, 1991a)
- *Exposure Factors Handbook* (EPA, 1997b)
- *Risk Assessment Guidance for Superfund—Volume I: Human Health Evaluation Manual Supplemental Guidance, Dermal Risk Assessment (Interim Guidance)* (EPA, 1998a)
- *Proposed Guidelines for Carcinogen Risk Assessment* (EPA, 1996b)
- *Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA, 1992b)

3.3 Chemicals of Potential Concern for Human Health

COPCs are those chemicals that are to be carried through the human health risk quantification process. This section summarizes the nature and extent of chemicals found in groundwater at the site and identifies the COPCs for the groundwater HHRA.

3.3.1 Data Used for COPC Selection

Groundwater data for the COPC selection process were the analytical results from all monitoring wells (MWs) and production wells (PWs) installed within the boundaries of the Troutdale site. Results from these wells were included in this evaluation irrespective of plant site location or hydrogeologic zone in which the well was screened. The MWs and PWs included in the COPC selection, and their respective water-bearing units (that is, shallow zone, intermediate zone, and deep zone) are summarized in Table 3-1.

Available groundwater data from the RI at the Troutdale site include results obtained between 1994 and 1998. Groundwater results from the four most recent sampling events at each individual well were selected for evaluation. Data from the four most recent sampling events were selected because they are considered to be the most representative of current conditions at each well. Any chemical that was detected in groundwater at least once during this time period was evaluated to determine whether it should be identified as a COPC for the HHRA.

Those chemicals detected in groundwater at least once during the four most recent sampling events and their summary statistics are presented in Table 3-2. A total of 38 chemicals were detected in groundwater at least once during the selected sampling rounds. This list was used to identify COPCs using the selection criteria described in the following subsections.

Table 3-1
Summary of Monitoring and Production Wells
Included in the Groundwater Screening Process

Station	Sample ID	Screened Interval or Location	Comments
MW03-175	MW03-175-13697-0	Deep Zone	
MW06-176	MW06-176-13497-0	Deep Zone	
MW08-169	MW08-169-23097-0	Deep Zone	
MW10-165	MW10-165-04998-0	Deep Zone	
MW12-184	MW12-184-13597-0	Deep Zone	
MW15-175	MW15-175-13597-0	Deep Zone	
MW21-176	MW21-176-23097-0	Deep Zone	
MW27-176	MW27-176-13397-0	Deep Zone	
MW28-160	MW28-160-13997-0	Deep Zone	
MW29-179	MW29-179-30997-0	Deep Zone	
MW32-165	MW32-165-31097-0	Deep Zone	
MW33-165	MW33-165-31097-0	Deep Zone	
MW48-165	MW48-165-22398-0	Deep Zone	
MW49-145	MW49-145-32297-0	Deep Zone	
PW03	PW03-29695-0	Deep Zone	
PW07	PW07-22894-0	Deep Zone	
PW08	PW08-34295-0	Deep Zone	
PW10	PW10-24097-0	Deep Zone	
MW03-098	MW03-098-31197-0	Intermediate Zone	
MW06-094	MW06-094-13397-0	Intermediate Zone	
MW08-127	MW08-127-13297-0	Intermediate Zone	
MW10-090	MW10-090-31497-0	Intermediate Zone	
MW12-092	MW12-092-31097-0	Intermediate Zone	
MW15-086	MW15-086-04798-0	Intermediate Zone	
MW21-063	MW21-063-13297-0	Intermediate Zone	
MW27-081	MW27-081-30897-0	Intermediate Zone	
MW29-090	MW29-090-04898-0	Intermediate Zone	
MW30-100	MW30-100-30997-0	Intermediate Zone	
MW31-095	MW31-095-30997-0	Intermediate Zone	
MW32-095	MW32-095-31097-0	Intermediate Zone	
MW33-095	MW33-095-22398-0	Intermediate Zone	
MW39-095	MW39-095-22698-0	Intermediate Zone	
MW47-094	MW47-094-23397-0	Intermediate Zone	
MW48-055	MW48-055-32397-0	Intermediate Zone	
MW49-095	MW49-095-04898-0	Intermediate Zone	
MW50-094	MW50-094-04898-0	Intermediate Zone	
MW51-069	MW51-069-13198-0	Intermediate Zone	
MW01-019	MW01-019-23397-0	Shallow Zone	
MW02-012	MW02-012-23297-0	Shallow Zone	
MW02-024	MW02-24-33895-0	Shallow Zone	Overdrilled and replaced by MW02-034 in Jan.1996.
MW02-034	MW02-034-23497-0	Shallow Zone	
MW03-017	MW03-017-04798-0	Shallow Zone	
MW04-019	MW04-019-05297-0	Shallow Zone	
MW05-025	MW05-025-04798-0	Shallow Zone	
MW06-024	MW06-024-13497-0	Shallow Zone	
MW07-024	MW07-024-13597-0	Shallow Zone	
MW08-027	MW08-027-13297-0	Shallow Zone	
MW09-030	MW09-030-23097-0	Shallow Zone	

Table 3-1
Summary of Monitoring and Production Wells Included in the Groundwater Screening Process

Station	Sample ID	Screened Interval or Location	Comments
MW10-023	MW10-023-04998-0	Shallow Zone	
MW11-017	MW11-017-23397-0	Shallow Zone	
MW12-021	MW12-021-05098-0	Shallow Zone	
MW13-022	MW13-022-23297-0	Shallow Zone	
MW14-015	MW14-015-23297-0	Shallow Zone	
MW15-024	MW15-024-13597-0	Shallow Zone	
MW16-014	MW16-014-04997-0	Shallow Zone	
MW17-016	MW17-016-23497-0	Shallow Zone	Abandoned in June 1998.
MW17-028	MW17-028-23497-0	Shallow Zone	
MW18-016	MW18-016-23497-0	Shallow Zone	
MW18-031	MW18-031-04997-0	Shallow Zone	
MW19-013	MW19-013-23198-0	Shallow Zone	
MW20-026	MW20-026-04997-0	Shallow Zone	
MW21-012	MW21-012-32596-0	Shallow Zone	Abandoned in June 1998.
MW21-025	MW21-025-23097-0	Shallow Zone	
MW22-027	MW22-027-30897-0	Shallow Zone	
MW23-025	MW23-025-23097-0	Shallow Zone	
MW24-010	MW24-010-05597-0	Shallow Zone	
MW25-024	MW25-024-23297-0	Shallow Zone	
MW25-035	MW25-035-05197-0	Shallow Zone	
MW26-012	MW26-012-04798-0	Shallow Zone	
MW27-045	MW27-045-30897-0	Shallow Zone	
MW29-033	MW29-033-05197-0	Shallow Zone	
MW30-030	MW30-030-05098-0	Shallow Zone	
MW31-034	MW31-034-30997-0	Shallow Zone	
MW32-040	MW32-040-31097-0	Shallow Zone	
MW33-033	MW33-033-31097-0	Shallow Zone	
MW34-038	MW34-038-31097-0	Shallow Zone	
MW35-038	MW35-038-31197-0	Shallow Zone	
MW36-006	MW36-006-30997-0	Shallow Zone	Abandoned in June 1998.
MW37-012	MW37-012-23797-0	Shallow Zone	
MW37-030	MW37-030-31497-0	Shallow Zone	
MW38-007	MW38-007-23397-0	Shallow Zone	
MW38-035	MW38-035-04798-0	Shallow Zone	
MW41-020	MW41-020-31597-0	Shallow Zone	
MW41-033	MW41-033-22398-0	Shallow Zone	
MW43-015	MW43-015-13398-0	Shallow Zone	
MW44-027	MW44-027-31597-0	Shallow Zone	
MW45-042	MW45-042-31197-0	Shallow Zone	
MW52-045	MW52-045-13198-0	Shallow Zone	
MW53-034	MW53-034-13198-0	Shallow Zone	

Table 3-2 Summary of Chemicals Detected in Groundwater											
Chemical Name	**Chemical Class**	**Units**	**Number Detected**	**Number Analyzed**	**Frequency of Detection (%)**	**Minimum Detected Value**	**Maximum Detected Value**	**Arithmetic Mean**	**Geometric Mean**	**Standard Deviation**	**Coefficient of Variation**	**95%UCL**
1,1,1-Trichloroethane	VOC	mg/L	5	92	5.43	0.0002	0.04199	0.0013	0.0006	0.0051	3.7916	2.22E-03
1,1-Dichloroethane	VOC	mg/L	9	92	9.78	0.0002	0.004	0.0007	0.0005	0.0013	1.8824	9.49E-04
1,1-Dichloroethene	VOC	mg/L	7	92	7.61	0.0003	0.003	0.0007	0.0005	0.0013	1.8728	9.09E-04
1,2-Dichlorobenzene	VOC	mg/L	1	92	1.09	0.0002	0.0002	0.0006	0.0005	0.0013	2.0139	8.39E-04
1,2-Dichloroethane	VOC	mg/L	1	92	1.09	0.002	0.002	0.0006	0.0005	0.0013	1.9640	8.60E-04
Acenaphthene	PAH	mg/L	1	94	1.06	0.00011	0.00011	0.0001	0.0001	0.0003	3.3799	1.18E-04
Aluminum	Metal	mg/L	112	255	43.92	0.0529	63.2	1.5298	0.1089	5.5573	3.6326	2.10E+00
Antimony	Metal	mg/L	2	166	1.20	0.00109	0.0052	0.0026	0.0025	0.0018	0.6813	2.84E-03
Arsenic	Metal	mg/L	50	258	19.38	0.00089	0.10999	0.0039	0.0025	0.0102	2.6185	4.93E-03
Barium	Metal	mg/L	123	195	63.08	0.00999	0.73799	0.0414	0.0261	0.0639	1.5425	4.90E-02
Beryllium	Metal	mg/L	80	260	30.77	0.0003	0.02439	0.0010	0.0003	0.0026	2.5241	1.31E-03
Boron	Metal	mg/L	1	11	9.09	0.18	0.18	0.0618	0.0562	0.0392	0.6341	8.32E-02
Cadmium	Metal	mg/L	1	174	0.57	0.00279	0.00279	0.0011	0.0010	0.0007	0.6838	1.17E-03
Calcium	Metal	mg/L	51	51	100.00	2.48	337	31.5869	18.1859	53.0052	1.6781	4.40E+01
Chloromethane	VOC	mg/L	1	92	1.09	0.0001	0.0001	0.0006	0.0005	0.0013	2.0159	8.39E-04
Chromium	Metal	mg/L	15	258	5.81	0.0101	0.12399	0.0068	0.0054	0.0112	1.6510	7.92E-03
Chrysene	PAH	mg/L	1	95	1.05	0.00011	0.00011	0.0001	0.0000	0.0000	0.4282	5.45E-05
Copper	Metal	mg/L	66	206	32.04	0.00139	0.855	0.0096	0.0019	0.0622	6.4790	1.68E-02
Cyanide, Total	Metal	mg/L	40	206	19.42	0.012	1.17	0.0388	0.0127	0.1300	3.3488	5.38E-02
Fluorene	PAH	mg/L	1	95	1.05	0.00013	0.00013	0.0001	0.0001	0.0003	3.2807	1.20E-04
Fluoride	PAH	mg/L	92	134	68.66	0.25999	432	26.1806	2.2521	66.4792	2.5393	3.57E+01
Iron	Metal	mg/L	160	203	78.82	0.10199	121	8.0479	0.9855	17.3543	2.1564	1.01E+01
Lead	Metal	mg/L	31	258	12.02	0.001	0.043	0.0013	0.0006	0.0038	3.0382	1.65E-03
Magnesium	Metal	mg/L	51	51	100.00	1.04	42.5	7.9588	6.1247	6.9372	0.8716	9.59E+00
Manganese	Metal	mg/L	43	57	75.44	0.03659	7.17	0.7249	0.2009	1.2035	1.6604	9.92E-01
Mercury	Metal	mg/L	1	172	0.58	0.00075	0.00075	0.0001	0.0001	0.0001	0.5105	1.10E-04
Methylene chloride	VOC	mg/L	4	92	4.35	0.0001	0.0003	0.0011	0.0008	0.0025	2.2068	1.59E-03
Naphthalene	PAH	mg/L	4	94	4.26	0.0003	0.00086	0.0001	0.0001	0.0003	2.8815	1.43E-04
Nickel	Metal	mg/L	8	258	3.10	0.0425	0.279	0.0223	0.0201	0.0197	0.8818	2.43E-02
Potassium	Metal	mg/L	50	51	98.04	1.2	38.8	4.7092	3.0057	7.4607	1.5843	6.46E+00

Table 3-2
Summary of Chemicals Detected in Groundwater

Chemical Name	Chemical Class	Units	Number Detected	Number Analyzed	Frequency of Detection (%)	Minimum Detected Value	Maximum Detected Value	Arithmetic Mean	Geometric Mean	Standard Deviation	Coefficient of Variation	95%UCL
Selenium	Metal	mg/L	3	166	1.81	0.00499	0.00609	0.0025	0.0024	0.0005	0.2110	2.58E-03
Silver	Metal	mg/L	11	170	6.47	0.003	0.00949	0.0019	0.0017	0.0016	0.8429	2.13E-03
Sodium	Metal	mg/L	51	51	100.00	4.17	397	45.7408	24.4014	69.6636	1.5230	6.21E+01
Tetrachloroethene	VOC	mg/L	10	92	10.87	0.0002	0.37	0.0084	0.0006	0.0520	6.2034	1.74E-02
Toluene	VOC	mg/L	13	92	14.13	0.00018	0.013	0.0012	0.0006	0.0023	1.9177	1.57E-03
Trichloroethene	VOC	mg/L	2	92	2.17	0.0005	0.0006	0.0006	0.0005	0.0013	1.9986	8.44E-04
Vanadium	Metal	mg/L	12	179	6.70	0.0227	0.609	0.0193	0.0111	0.0594	3.0701	2.67E-02
Zinc	Metal	mg/L	7	166	4.22	0.0019	0.13799	0.0271	0.0250	0.0141	0.5219	2.89E-02

Note: Data presented include analyses from the four most recent sampling rounds for each specific well.

In addition to the onsite groundwater monitoring program, the RI background-sampling program provided groundwater concentrations measured at selected background locations. These data are provided in Appendix B and discussed in Section 3.4.3.3.

3.3.2 Criteria for Selection of COPCs

Criteria considered in identifying COPCs for sitewide groundwater are as follows:

- Analytical reliability
- Availability of toxicity factors
- Risk-based screening

The decision process used for selection of human health COPCs is presented in Figure 3-1.

3.3.2.1 Analytical Reliability

As a first step in the selection process, analytical data were evaluated to determine whether the data are valid, representative, and usable for risk assessment. To the extent possible, the data used for risk analyses for the RMC-Troutdale site met requirements outlined in *Guidance for Data Usability in Risk Assessment (Part A)* (EPA, 1992c). One important component of these requirements is attaining detection limits that achieve risk-based concentrations for specific media. The methods and detection limits for analyzing samples for the project were designed to produce data of sufficient quality for risk assessment. Information on analytical methods and detection limits is presented in the *Draft Sampling and Analysis Plan* (SAP) (CH2M HILL, 1997c).

Data validation procedures used are also described in the Quality Assurance Project Plan contained in the SAP (CH2M HILL, 1997c). Data were reviewed to eliminate results that might represent contamination of samples in the laboratory or in the field or that fail to meet quality control guidelines (for example, insufficient surrogate spike recovery). Positive detects and estimated results (data with a "J" qualifier) that met data validation requirements were considered usable for risk assessment.

3.3.2.2 Availability of Toxicity Factors

Another criterion for identifying a chemical as one of potential concern was the availability of a toxicity value established by EPA, such as cancer slope factors and reference dose (RfD) values (see Section 3.5 for definitions). If a toxicity value was not available from a reliable EPA source, then the chemical was not included in the risk quantification process. It should be recognized, however, that lack of an available toxicity value does not preclude a chemical's toxicity. Chemicals eliminated by this criterion were reevaluated to determine whether they might represent localized high-concentration areas (hot spots) at RMC-Troutdale, or whether they might contribute to overall risk on the basis of prevalence, concentration, or toxicity.

Calcium, lead, magnesium, potassium, and sodium are the only chemicals detected in groundwater that do not have available toxicity values. Calcium, magnesium, potassium, and sodium are common groundwater constituents and considered to be essential nutrients for human nutrition. None of these chemicals lacking of toxicity values are expected to be the result of site releases and therefore are not deemed significant in this assessment.

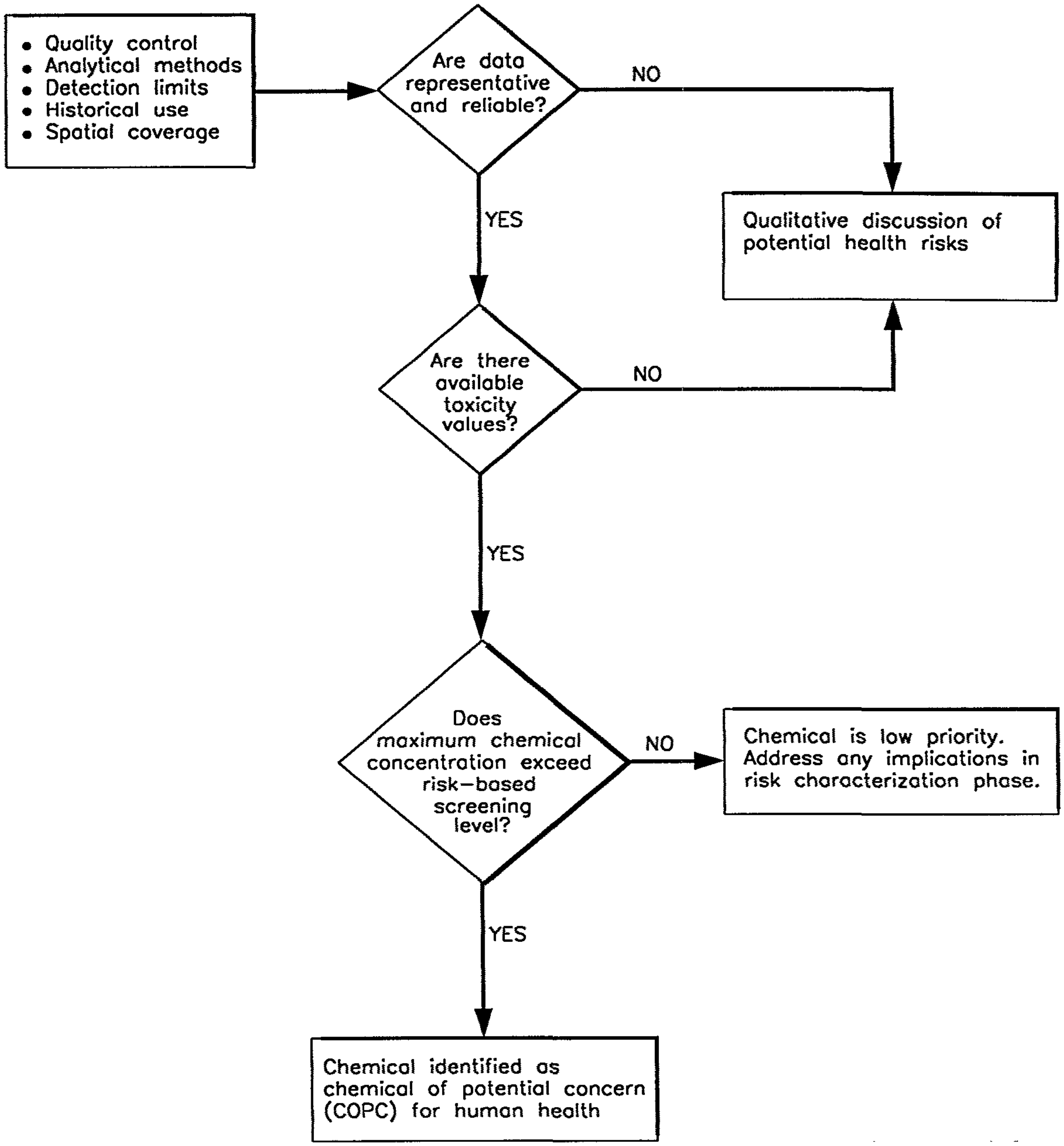

Figure 3-1
IDENTIFICATION OF CHEMICALS OF POTENTIAL CONCERN FOR HUMAN HEALTH
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment
Part 2—Groundwater

CH2MHILL

Although lead does not have an available cancer slope factor or RfD for the evaluation of health risks, groundwater concentrations are evaluated separately in the Tier 1 RA by comparison with a health-based action level for tap water.

3.3.2.3 Risk-Based Screening

Groundwater COPCs were selected in accordance with the *Draft EPA Region 10 Supplemental Risk Assessment Guidance for Superfund* (EPA, 1996a). The maximum concentration of each chemical detected in groundwater was compared with the EPA Region 9 preliminary remediation goal (PRG) for tap water (EPA, 1998c). If the maximum chemical concentration in groundwater was less than a target cancer risk of 1×10^{-6} or a noncancer hazard quotient (HQ) of 0.1 (calculated as 10 percent of the Region 9 PRG for noncarcinogens), it was eliminated from consideration as a COPC. The concepts of cancer risk and hazard quotient are described in Section 3.5.

A comparison of chemical concentrations in groundwater with risk-based screening values for tap water is presented in Table 3-3. The maximum concentrations for 18 of the 38 chemicals detected in groundwater exceeded the risk-based screening values. Therefore, 18 chemicals were selected as COPCs and carried forward into the Tier 1 RA (Section 3.6.4).

3.4 Human Exposure Assessment

The exposure assessment component of the HHRA identifies the means by which individuals on or near the Troutdale site may contact chemicals in groundwater. It addresses exposures that may result under current site conditions and from reasonably anticipated potential future uses of the site and the surrounding areas. The exposure assessment also identifies the populations that may be exposed, the routes by which these individuals may become exposed, and the magnitude, frequency, and duration of potential exposures.

The exposure assessment step of the HHRA for the RMC-Troutdale facility includes the following tasks:

- Development of exposure assumptions for potentially complete exposure pathways
- Calculation of chemical intake for COPCs
- Computation of exposure point concentrations

The results of these tasks are discussed in the following subsections.

3.4.1 Human Exposure Assumptions

Estimation of exposure requires numerous assumptions to describe potential exposure situations. These assumptions, based on estimates of body weights, media intake levels, and exposure frequencies and durations, are provided by various EPA guidance documents (listed in Section 3.2).

Upper-bound exposure assumptions are used to estimate "reasonable maximum" exposure (RME) conditions to provide a bounding estimate on exposure. More typical or average-case exposure parameters are also used to help account for some of the uncertainties resulting from the use of RME assumptions. Table 3-4 lists the exposure parameters used to generate RME or average-case risk estimates under both current and future land use conditions.

Table 3-3
Comparison of Concentrations Detected in Groundwater with Risk-Based Screening Levels for Tap Water

Chemical Name	Maximum Detected Value[1]	Risk-Based Screening Level[2]	Is Maximum Detected Value > Risk-Based Screening Level?
1,1,1-Trichloroethane	4.20E-02	7.92E-02	No
1,1-Dichloroethane	4.00E-03	8.11E-02	No
1,1-Dichloroethene	3.00E-03	4.56E-05	Yes
1,2-Dichlorobenzene	2.00E-04	3.70E-02	No
1,2-Dichloroethane	2.00E-03	1.23E-04	Yes
Acenaphthene	1.10E-04	3.65E-02	No
Aluminum	6.32E+01	3.65E+00	Yes
Antimony	5.20E-03	1.46E-03	Yes
Arsenic	1.10E-01	4.48E-05	Yes
Barium	7.38E-01	2.56E-01	Yes
Beryllium	2.44E-02	7.30E-03	Yes
Boron	1.80E-01	3.29E-01	No
Cadmium	2.79E-03	1.83E-03	Yes
Calcium	3.37E+02	NA	NA
Chloromethane	1.00E-04	1.51E-03	No
Chromium	1.24E-01	1.83E-01	No
Chrysene	1.10E-04	9.21E-03	No
Copper	8.55E-01	1.36E-01	Yes
Cyanide, Total	1.17E+00	7.30E-02	Yes
Fluorene	1.30E-04	2.43E-02	No
Fluoride	4.32E+02	2.19E-01	Yes
Iron	1.21E+02	1.10E+00	Yes
Lead	4.30E-02	4.00E-04	Yes
Magnesium	4.25E+01	NA	NA
Manganese	7.17E+00	1.70E-01	Yes
Mercury	7.50E-04	1.10E-03	No
Methylene chloride	3.00E-04	4.28E-03	No
Naphthalene	8.60E-04	6.20E-04	Yes
Nickel	2.79E-01	7.30E-02	Yes
Potassium	3.88E+01	NA	NA
Selenium	6.09E-03	1.83E-02	No
Silver	9.49E-03	1.83E-02	No
Sodium	3.97E+02	NA	NA
Tetrachloroethene	3.70E-01	1.08E-03	Yes
Toluene	1.30E-02	7.23E-02	No
Trichloroethene	6.00E-04	1.64E-03	No
Vanadium	6.09E-01	2.56E-02	Yes
Zinc	1.38E-01	1.10E+00	No

[1] Maximum concentration from any well during the four most recent sampling rounds.
[2] Risk-based screening levels equivalent to ELCR = 10^{-6} or HQ = 0.1 under a residential scenario.
NA = not available.

Table 3-4
Summary of Exposure Assumptions for Occupational and Residential Exposure Scenarios

Exposure Factor		Occupational		Residential	
	Units	Ave	RME	Ave	RME
Body weight	kg	70[a]	70[a]	70[a]	70[a]
Drinking water ingestion rate	L/day	1[a]	1[a]	1.4[b]	2[a]
Inhalation rate	m^3/day	15.2[b]	20[a]	15.2[b]	20[a]
Volatilization factor-k	L/m^3	0.5[c]	0.5[c]	0.5[c]	0.5[c]
Exposed body parts	--	Entire body	Entire body	Entire body	Entire body
Exposed skin surface area	*cm^2*	18,000[d]	18,000[d]	18,000[d]	18,000[d]
Skin permeability constant, K_p	cm/hr	chemical specific	chemical specific	chemical specific	chemical specific
Showering exposure time	hr/event	0.17[d]	0.25[d]	0.17[d]	0.25[d]
Showering event frequency	events/day	1[d]	1[d]	1[d]	1[d]
Exposure frequency	days/yr	250[a]	250[a]	273[e]	350[d]
Years exposed	yr	6.6[b]	25[a]	9[b]	30[b]
Averaging time Noncancer	yr	6.6[b]	25[a]	9[b]	30[b]
Cancer	yr	70[a]	70[a]	70[a]	70[a]

[a] EPA, 1991.

[b] EPA, 1997b.

[c] EPA, 1991c.

[d] EPA, 1998a.

[e] CH2M HILL, 1999a.

The assumptions used are specific to the exposure scenarios identified for each groundwater exposure setting at RMC-Troutdale. The scenarios were selected based on discussions with EPA and DEQ during the RI, and are consistent with the reasonably anticipated future land uses described in the conceptual exposure model (Section 2).

As described in the conceptual site model, potential exposure settings considered for the groundwater HHRA include:

- **Current Onsite Occupational Use.** Potential current occupational exposure to chemicals in main plant area groundwater by ingestion and by dermal contact during showering.[1]
- **Current Offsite Occupational Use.** Potential current offsite occupational exposure to chemicals in downgradient groundwater (Sundial Marine Tug & Barge and Gresham Sand & Gravel) by ingestion and by dermal contact during showering.[1]
- **Future Onsite Occupational Use.** Potential future occupational exposure to chemicals in main plant area groundwater by ingestion and by dermal contact and inhalation of VOCs during showering.
- **Future Offsite Occupational and Residential Use.** Potential future occupational or residential exposure to chemicals in downgradient groundwater by ingestion and by dermal contact during showering.[1]

For each of these settings, pathways, and routes, chemical intake was calculated as described in the following section.

3.4.2 Calculation of Chemical Intake

Chronic exposure (that is, chronic daily intake or CDI) is expressed in terms of milligrams of chemical contacting the body per kilogram body weight per day (mg/kg-day). The following equation was used to calculate the chemical intake associated with the ingestion of groundwater:

$$Intake = \frac{C_w \times IR_w \times EF \times ED}{BW \times AT \times 365\ days/year}$$

where:

C_W	=	Chemical concentration in groundwater (mg/L)
IR_W	=	Groundwater ingestion rate (L/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Adult body weight (kg)
AT	=	Averaging time (days)

The parameters for estimating chemical intake from the ingestion of constituents in groundwater are presented in Table 3-4.

[1] Inhalation of VOCs during showering is not a complete exposure pathway for current or future offsite or current onsite exposure settings.

Chemical intake from dermal contact with groundwater was estimated using the following equation:

$$Intake = \frac{C_w \times SA \times Kp \times EF \times ED \times ET \times 1L/1{,}000\ cm^3}{BW \times AT \times 365\ days/year}$$

where:

C_W	=	Chemical concentration in groundwater (mg/L)
SA	=	Exposed skin surface area (cm^2)
Kp	=	Dermal permeability coefficient (cm/hr)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
ET	=	Exposure time (hours/day)
BW	=	Adult body weight (kg)
AT	=	Averaging time (days)

The parameters used to estimate exposure from dermal contact with groundwater are presented in Table 3-4. Chemical-specific dermal permeability coefficients (Kp) are derived from *Dermal Exposure Assessment: Principles and Applications* (EPA, 1992a).

Chemical intake from inhaling VOCs in groundwater was estimated using the following equation:

$$Intake = \frac{C_w \times IR_a \times VF \times EF \times ED}{BW \times AT \times 365\ days/year}$$

where:

C_W	=	Chemical concentration in groundwater (mg/L)
IR_a	=	Inhalation rate (m^3/day)
VF	=	Volatilization factor (L/m^3) (Andelman, 1990)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
ET	=	Exposure time (hours/day)
BW	=	Adult body weight (kg)
AT	=	Averaging time (days)

The parameters used to estimate exposure from inhalation of VOCs are presented in Table 3-4. Volatile chemicals considered for this pathway are operationally defined as those COPCs with a Henry's Law constant greater than 10^{-5} atmosphere-cubic meter per mole (atm-m^3/mole) and a molecular weight less than 200 grams per mole (EPA, 1991c).

3.4.3 Estimation of Exposure Point Concentrations

As previously described, a tiered approach was used to estimate health risks for groundwater at the Troutdale facility. This section describes the procedures used to estimate the exposure point concentrations (EPCs) for the Tier 1 and Tier 2 RAs. Because the data sets and approaches for Tier 1 and 2 were different, the derivations of exposure concentrations are discussed separately below.

3.4.3.1 Tier 1 Exposure Concentrations

The purpose of the Tier 1 RA was to identify which of the 18 selected COPCs present in sitewide groundwater (at any location or hydrogeologic zone) exist at concentrations that could feasibly pose risk at relevant exposure points (that is, where drinking wells are currently placed or could reasonably be placed in the future), and should be carried into Tier 2. To do this, chemical intakes and risk estimates were calculated during Tier 1 for each individual well at the RMC facility. Any chemicals in sitewide groundwater with concentrations exceeding specified target risk levels (see Section 3.6) during Tier 1 were selected for identification of EPCs in Tier 2 (using the modeling approaches described below). The Tier 1 EPCs were estimated using direct chemical measurement of groundwater from each well from the four most current rounds of data. The maximum detect of each COPC from the four most current rounds of data was used for the well-specific evaluation. The results of the Tier 1 exposure and risk estimates are described in Section 3.6.

3.4.3.2 Tier 2 Exposure Concentrations

For the subset of groundwater COPCs identified during Tier 1 as needing to be carried forward into the Tier 2 RA, EPCs were estimated at the most relevant exposure points at or near the RMC facility. EPCs were estimated differently for each of the four exposure settings described in Section 3.4.3, and sometimes differently for an individual COPC (depending on available data sources).

The most relevant exposure points for onsite and offsite groundwater were identified as locations where current human use of groundwater is currently occurring, or where future well placements are most feasible. Feasible well placement locations were selected based on consideration of reasonably anticipated future land use, groundwater flow direction, current groundwater concentration data, and review of the results of the regional well survey (see Section 3 of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, 1999b). For future settings (both onsite and offsite), exposure points were located where the highest potential for exposure to COPCs could occur. The exposure points evaluated were agreed to in discussions with EPA and DEQ during the 1999 monthly meetings. These exposure points are as follows:

- **Current Onsite Exposure Point** – At the drinking water tap currently supplying production well water to the RMC facility.
- **Future Onsite Exposure Point** – At well PW08, which contains higher concentrations of fluoride than are observed in tap water or other individual production wells.
- **Current Offsite Exposure Point** – At the drinking water tap supplying well water at Sundial Marine Tug & Barge and Gresham Sand & Gravel. These are identified as the only currently active wells downgradient of RMC.
- **Future Offsite Exposure Point** – At a hypothetical well located in the northeast corner of Fairview Farms, where the highest concentrations of fluoride in offsite groundwater are present downgradient of the RMC facility.

EPCs at each of these exposure points were estimated using either directly measured groundwater concentrations at the wells, or concentrations modeled spatially and temporally, as described in the following subsections. For the purpose of calculating EPCs, when a chemical was analyzed for but not detected at or above the method reporting limit (MRL), one-half the MRL was used as a proxy-value for calculating intake of groundwater.

Current Onsite Water Use. For the current onsite exposure setting, RMC tap water measurements reflect the most realistic measures of potential current exposure. Concentration data for all constituents of concern identified during Tier 1 were not available, however, from tap measurements. Therefore, the following hierarchy was used to identify tap water EPCs:

- If the constituent of concern was analyzed in RMC tap water, EPCs were calculated as the 95 percent upper confidence limit (95 percent UCL) concentrations using data measured beginning in 1998. The EPCs were used to estimate the 25-year exposure concentrations under the current groundwater use setting. This represents a reasonable maximum estimate of exposure, since fluoride concentrations measured in tap water and individual production wells have been elevated—in comparison with previous years—since early 1998, when RMC went into full production (see Figure 3-2).
- If a constituent of interest was not analyzed in RMC tap water during previous investigations, then available information from RMC's five recently active production wells (PW03, PW07, PW08, PW10, and PW18) was used to estimate EPCs. The data from the four most recent sampling events for these wells were used to calculate the 95 percent UCL as the EPC. Use of production well measurements presumed equal production well use, and concentrations were equally weighted to estimate current exposure. Constituents analyzed but not detected in production wells were considered absent from tap water.

Future Onsite Water Use. To estimate future onsite tap water concentrations, it was assumed that onsite water use would be reduced to nominal industrial conditions, such that groundwater would be obtained from only one production well. In addition, production well PW08 was selected to predict "worst-case" future chemical exposure concentrations at the property. Similar to the current onsite setting, the following hierarchy was used to identify tap water EPCs:

- If the constituent of concern was analyzed in PW08, EPCs were estimated using direct chemical measurement of groundwater from this well. For these constituents (for example, fluoride), the 95 percent UCL concentrations measured since May 1998 were used to estimate 25-year exposure concentrations under the current groundwater use setting. Fluoride concentrations measured in individual production wells have been elevated since May 1998, when RMC went into full production, in comparison with previous years.
- If a constituent of interest was not analyzed in PW08, then EPCs were estimated by interpolating concentrations from measured concentrations in the most contaminated nearby shallow water-bearing zones. The interpolation approach is described below.

Interpolation of Future Tap Water Concentrations from Shallow-Zone Concentrations. EPCs interpolated from shallow-zone concentrations were estimated using the following equation:

$$EPC_{tap} = \frac{C_{shallow}}{MF}$$

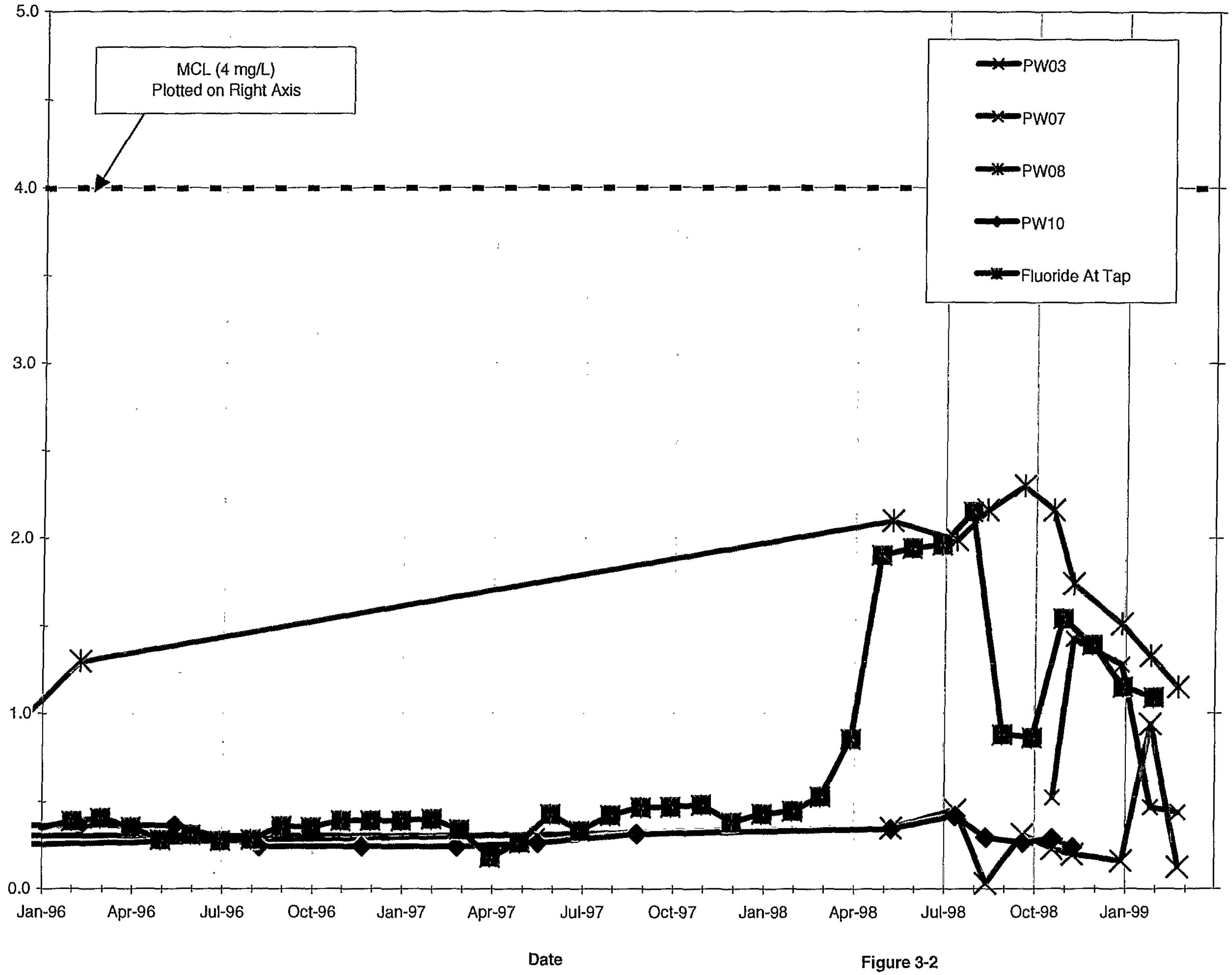

Figure 3-2
Fluoride Concentrations in Production Wells and Tap Water
(January 1996 Through March 1999)
Reynolds Metals Company - Troutdale, Oregon
Baseline Risk Assessment, Part 2-Groundwater

PDX1830D.XLS

where:

EPC_{tap}	=	Exposure point concentration in future tap water
$C_{shallow}$	=	95 percent UCL concentrations measured in nearby shallow monitoring wells during the four most recent sampling events
MF	=	Mixing factor

This interpolation approach assumes that the empirical relationship observed onsite for fluoride between the shallow zone and the production wells provides a conservative estimate for other constituents. Because fluoride is known to migrate in groundwater more readily than other site COPCs, this approach provides a high-end estimate of future tap water EPCs for other, less mobile constituents.

The mixing factor (MF) describes the attenuation that occurs for a constituent between the actual sampling point and the tap. It considers the mixing effects that occur within a future production well because of the three-dimensional nature of the well's capture zone, which captures groundwater from zones containing constituents at elevated concentrations and from zones containing lower constituent concentrations (including background levels). The mixing factor is calculated by using fluoride concentrations in production and monitoring wells as the indicator of the degree of attenuation that could occur. In addition, the mixing factor accounts for the effects of variations in water demand and wellfield operations on chemical concentrations that would be measured at a future tap.

The mixing factor was derived from the fluoride concentrations measured in PW08 and in the monitoring well cluster (location MW33-095) closest to the active production wells. The following formula was used to calculate the mixing factor:

$$MF_{Future} = \frac{[F^-]_{MW33-095}}{[F^-]_{PW08}}$$

where:

MF_{Future}	=	mixing factor for future onsite water use
$[F^-]_{MW33-095}$	=	arithmetic mean fluoride concentration measured historically at MW33-095.
$[F^-]_{PW08}$	=	arithmetic mean of the measured fluoride concentrations in PW08 during the period May 1998 through April 1999.

Fluoride concentrations measured in PW08 were used in the denominator because this well was selected to represent worst-case future industrial conditions. The arithmetic mean for fluoride measured at PW08, based on a total of 12 measurements taken from May 1998 through April 1999, is 1.78 mg/L, highest of all production wells. Fluoride concentrations measured in MW33-095 were used in the numerator because:

- This well is in the direct flow path from known fluoride sources (specifically scrap yard).
- It is a good indicator of water quality concentration changes in deeper groundwater and in the production wells [see Section 5.2.2.2 of the *Draft Groundwater Remedial Investigation Report* (CH2M HILL, 1999b)].

- It provides a conservative estimate of the MF because it contains lower fluoride concentrations than have been measured in shallower sampling locations (monitoring wells and Geoprobes) in the UGS close to the scrap yard soil and debris area.

To provide additional conservatism in the value of the mixing factor, the concentration value at MW33-095 was selected to be the arithmetic mean fluoride concentration. The arithmetic mean for fluoride measured in MW33-095 is 83 mg/L, based on seven measurements taken from February 1997 through March 1999. This is substantially lower than fluoride concentrations as high as 141 mg/L that have been measured at this well.

Consequently, the mixing factor used for the future onsite setting is equal to:

$$MF_{Future} = \frac{83\ mg\ /\ L}{1.78\ mg\ /\ L} = 47$$

It should be recognized that this approach assumes that the observed relationship between PW08 and MW33-095 reflects steady-state conditions. The results of the Tier 2 exposure and risk estimates for the future onsite setting are described in Section 3.6.

Current Offsite Water Use. To estimate current offsite tap water concentrations, two offsite downgradient wells were selected to represent offsite conditions. Both the Sundial Marine Tug & Barge and Gresham Sand & Gravel wells are used as potable and industrial supply wells and are located northwest of Company Lake. The Sundial Marine Tug & Barge (SM01) well is screened from 228 to 233 feet bgs and is used for manufacturing processes, provides drinking water to approximately 30 people who work onsite, and is used to fill potable water tanks on Coast Guard vessels and tugs that require servicing. The Gresham Sand & Gravel (GS01) well is screened from 120 to 130 feet bgs and is the only water supply at this location. It serves as a domestic well to an uninhabited house, as well as supplying water to a guard shack toilet and sink.

Tap water concentrations were measured at both locations between September 1994 and February 1997 (a total of 4 sampling rounds at each location). The EPCs were calculated as the 95 percent UCL on the mean concentration from these two wells. The results of the Tier 2 exposure and risk estimates for the current offsite setting are described in Section 3.6.

Future Offsite Water Use. For the future offsite exposure setting, exposure concentrations for fluoride were estimated using a site-scale groundwater flow model (CH2M HILL, 1999c) and the existing distribution of fluoride in groundwater (CH2M HILL, 1999b). The exposure concentration estimation procedure assumes that there will be a well located in the northeast corner of Fairview Farms. This "hypothetical well" is presumed constructed at the location where the highest fluoride concentrations could potentially occur in offsite groundwater downgradient of the RMC facility and, based on our knowledge of groundwater flow, where they will be highest in the future (assuming no action) within the Fairview Farms property. An additional measure of conservativeness was introduced into the analysis by simulating pumping (and therefore exposure) as a steady-state, long-term event, rather than simulating intermittent periods of pumping and exposure.

The site-scale groundwater flow model was used to estimate concentrations by simulating a selected pumping regime and well design under both an occupational and a residential scenario. The simulated capture zones for the Fairview Farms hypothetical well were compared with the existing fluoride concentration distribution in groundwater. On the basis of this comparison, the net in-well fluoride concentration was derived for each future offsite exposure scenario (occupational or residential). A three-dimensional particle tracking was performed to delineate a 25-year capture zone for the hypothetical well. A 25-year period was selected because the time corresponds to the exposure duration of the occupational scenario. The assumed well pumping characteristics for each exposure scenario, the concentration of each particle within the model, and the particle's associated travel time, were used to calculate the arithmetic mean concentration of fluoride at the hypothetical well. A detailed description of the capture zone analysis for both the occupational and the residential exposure scenarios is presented in Appendix C. The well characteristics assumed for occupational and residential scenarios, and the resulting EPC estimates, are provided below.

Future Offsite Occupational Scenario. For the occupational use scenario, the Fairview Farms hypothetical well was pumped at a rate of 100 gpm, which corresponds to a well that could support light industrial activities. The selected depth interval is the same as for the Gresham Sand & Gravel well, which is screened over a depth of 120 to 130 feet bgs. The net concentration of fluoride in the Fairview Farms hypothetical well (or the EPC) was 5.8 mg/L for this exposure scenario.

Future Offsite Residential Scenario. For the residential use scenario, the Fairview Farms hypothetical well was pumped at a rate of 5 gpm, which corresponds to a typical instantaneous yield for a domestic water supply well. The well was simulated at the same depth as the well that yielded the highest measured concentration of fluoride during site investigations (GP45, a temporary Geoprobe® sampling location screened at an intermediate depth of 82 feet bgs). The net concentration of fluoride in the hypothetical well was 7.1 mg/L for this exposure scenario.

For nonfluoride constituents identified during Tier 1 for evaluation during Tier 2, an evaluation was conducted to determine whether elevated site groundwater concentrations were located within the capture zone of the hypothetical well. The model simulations described previously were used to evaluate whether the capture zone for the hypothetical well includes any of these locations. The capture zone analyses indicated that none of the onsite monitoring well locations with concentrations exceeding MCLs lie within the capture zone of the hypothetical well under either the occupational or the residential exposure scenario. Therefore, nonfluoride constituents were excluded from the risk calculations for the Fairview Farms hypothetical well.

3.4.3.3 Background Exposure Concentrations

The RI background-sampling program provided groundwater concentrations measured at selected background locations. Background groundwater concentrations of naturally occurring inorganic chemicals were established using numerous samples taken from locations considered upgradient or cross-gradient of the facility and not affected by site activities. This information helps identify whether onsite COPC concentrations are likely site-related or attributed to natural local conditions. Available background wells include MW03 (screened at shallow, intermediate, and deep zones) and MW05 (screened at shallow zone) installed at the RMC site; six City of Troutdale wells (all screened at deep zone); and seven Portland Water Bureau wells (all screened at deep zone in the sand gravel aquifer system). A summary of inorganic chemical concentrations detected in background wells of the Troutdale site is provided in Appendix B.

The Tier 2 EPCs established for each current and future exposure setting were compared with background concentrations of naturally occurring chemicals. If the EPC developed was less than the background concentration of the naturally occurring chemical, it was not considered in the risk calculation during the Tier 2 RA.

3.5 Toxicity Assessment for Human Health

This toxicity assessment evaluates the relationship between the magnitude of exposure to a chemical at the Troutdale site and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with chemical exposure (EPA, 1989). The toxicity assessment contains two steps: hazard characterization and dose-response evaluation. These two components are discussed in the following two subsections.

3.5.1 Hazard Characterization

Hazard characterization identifies the types of toxic effects a chemical can exert. For the toxicity assessment, chemicals can be divided into two broad groups on the basis of their effects on human health: noncarcinogens and carcinogens. This classification has been selected because health risks are calculated quite differently for carcinogenic and noncarcinogenic effects, and separate toxicity values have been developed for them.

Carcinogens are those chemicals suspected of causing cancer following exposure; noncarcinogenic effects cover a wide variety of systemic effects, such as liver toxicity or developmental effects. Some chemicals (for example, arsenic) are capable of eliciting both carcinogenic and noncarcinogenic responses, and therefore these carcinogens are also evaluated for systemic (noncarcinogenic) effects.

For cancer effects, EPA has developed a carcinogen classification system (EPA, 1986) using a weight-of-evidence approach to classify the likelihood that a chemical is a human carcinogen. Although this classification scheme has been superseded in recent guidance (EPA, 1996b), it is used in this report because EPA has not fully implemented the newer guidance. Information considered in developing the classification includes human studies of the association between cancer incidence and exposure, as well as long-term animal studies under controlled laboratory conditions. Other supporting evidence includes short-term tests for genotoxicity, metabolic and pharmacokinetic properties, toxicological effects other than cancer, structure-activity relationships, and physical and chemical properties of the chemical. A description of the weight-of-evidence classification is presented in Table 3-5.

For noncancer effects, toxicity values (Section 3.5.2.2) are derived on the basis of the critical toxic endpoint (that is, the most sensitive adverse effect following exposure). The chemicals detected at the Troutdale site during the RI that have been identified as having documented systemic effects are listed in Table 3-6, along with their critical toxic effects. Of the chemicals identified, 13 have been classified by EPA as known (Group A), probable (Groups B1 and B2), or possible (Group C) human carcinogens. These chemicals and their EPA classifications are presented in Table 3-6.

Table 3-5
EPA Weight-of-Evidence Classification System for Carcinogenicity

Group	Description
A	Human carcinogen, based on evidence from epidemiological studies
B1 or B2	Probable human carcinogen B1 indicates that limited human data are available B2 indicates sufficient evidence in animals and inadequate or no evidence in humans
C	Possible human carcinogen, based on limited evidence in animals
D	Not classifiable as to human carcinogenicity
E	Evidence of noncarcinogenicity for humans

Source: EPA, 1986.

3.5.2 Dose-Response Evaluation

The magnitude of toxicity of a chemical depends on the dose to a receptor. Dose refers to exposure to a chemical concentration over a specified period of time. Human exposures are generally classified as acute (typically less than 2 weeks), subchronic (about 2 weeks to 7 years), or chronic (usually 7 years to a lifetime). This RA specifically addresses chronic exposure. Acute exposures and risks are evaluated only when chronic exposure estimates pose a high risk.

A dose-response curve describes the relationship between the degree of exposure (the dose) and the incidence of the adverse effects (the response) in the exposed population. EPA uses this dose-response information to establish toxicity values for particular chemicals, as described in the following paragraphs.

3.5.2.1 Toxicity Values

Toxicity values (cancer slope factors and noncancer reference doses) reflect the dose-response relationship for COPCs and allow quantification of risk from exposure. The toxicity values used in this RA were obtained from the following sources:

- The Integrated Risk Information System (IRIS), a database available through the EPA Environmental Criteria and Assessments Office (ECAO) in Cincinnati, Ohio. IRIS, prepared and maintained by EPA, is an electronic database containing health risk and EPA regulatory information on specific chemicals (EPA, 1998b).
- The Health Effects Assessment Summary Tables (HEAST), provided by the EPA Office of Solid Waste and Emergency Response (OSWER) (EPA, 1997a), is a compilation of toxicity values published in various health effects documents issued by EPA.

The primary source of toxicity values is EPA's IRIS database. If a toxicity value was not available from IRIS, then the latest available HEAST were used. For some chemicals, no toxicity value from either IRIS or HEAST may be available, and toxicity values provided by EPA's *Region 3 Risk-Based Concentration Table* (EPA, 1998d) are used.

Table 3-6
Noncancer and Carcinogenic Toxicity Values for Chemicals Detected in Groundwater

Chemical	Carcinogen Classification	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Source	Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Source	Oral RfD (mg/kg-day)	Source	Inhalation Reference Dose (mg/kg-day)	Source	Skin Permeability Constant (cm/hr)[d]	Critical Systemic Effect
1,1,1-Trichloroethane	D	NA	--	NA	--	9.00E-02	--	2.86E-01	--	1.70E-02	--
1,1-Dichloroethane	C	NA	--	NA	--	1.00E-02	--	1.43E-01	--	8.90E-03	--
1,1-Dichloroethene	C	6.00E-01	a	1.75E-01	a	9.00E-03	a	5.71E-02	--	1.60E-02	Hepatic lesions
1,2-Dichlorobenzene	D	NA	--	NA	--	9.00E-02	a	NA	--	6.10E-02	No adverse effects observed
1,2-Dichloroethane	B2	9.10E-02	a	9.10E-02	a	NA	--	2.86E-03	--	5.30E-03	--
Acenaphthene	NA	NA	--	NA	--	6.00E-02	a	NA	--	NA	Hepatotoxicity
Aluminum	NA	NA	--	NA	--	1.00E+00	c	NA	--	1.00E-03	Minimal neurotoxicity
Antimony	D	NA	--	NA	--	4.00E-04	a	NA	--	1.00E-03	Longevity, blood glucose, cholesterol
Arsenic	A	1.50E+00	a	1.51E+00	a	3.00E-04	a	NA	--	1.00E-03	Hyperpigmentation, keratosis, and possible vascular complications
Barium	D	NA	--	NA	--	7.00E-02	a	1.43E-04	--	1.00E-03	Increased blood pressure
Beryllium	B2	4.30E+00	--	8.40E+00	a	5.00E-03	a	NA	a	1.00E-03	Intestinal lesions
Boron	D	NA	--	NA	--	9.00E-02	a	5.71E-03	--	1.00E-03	Testicular atrophy, spermatogenic arrest
Cadmium (water)	B1	NA	--	6.30E+00	--	5.00E-04	a	NA	--	1.00E-03	Significant proteinuria in chronic human studies
Calcium	NA	NA	--	NA	--	NA	--	NA	--	1.00E-03	--
Chloromethane	C	1.30E-02	--	6.30E-03	--	3.60E-03	--	NA	--	4.20E-03	--
Chromium, Hexavalent	A	NA	--	4.20E+01	a	5.00E-03	a	NA	a	1.00E-03	No adverse effects observed
Chrysene	B2	7.30E-03	c	NA	--	NA	--	NA	--	NA	--
Copper	D	NA	--	NA	--	3.70E-02	b	NA	--	1.00E-03	Gastrointestinal system - irritation
Cyanide	D	NA	--	NA	--	2.00E-02	a	NA	--	1.00E-03	No adverse effects observed
Fluorene	D	NA	--	NA	--	4.00E-02	a	NA	--	NA	Decreased red blood cells, packed cell volume and hemoglobin
Fluoride	NA	NA	--	NA	--	6.00E-02	a	NA	--	1.00E-03	Dental fluorosis, a cosmetic effect
Iron	NA	NA	--	NA	--	3.00E-01	c	NA	--	1.00E-03	Not available
Lead	B2	NA	--	NA	--	NA	--	NA	--	1.00E-03	--
Magnesium	NA	NA	--	NA	--	NA	--	NA	--	1.00E-03	--
Manganese	D	NA	--	NA	--	1.40E-01	a	1.43E-05	a	1.00E-03	Central nervous system effects
Mercury	D	NA	--	NA	--	3.00E-04	c	8.57E-05	a	1.00E-03	Autoimmune effects
Methylene chloride	B2	7.50E-03	a	1.65E-03	a	6.00E-02	a	8.57E-01	--	4.50E-03	Liver toxicity
Naphthalene	D	NA	--	NA	--	4.00E-02	a	NA	a	6.90E-02	Decreased body weight gain
Nickel	D	NA	--	NA	--	2.00E-02	a	NA	--	1.00E-03	Decreased body and organ weights
Potassium	NA	NA	--	NA	--	NA	--	NA	--	1.00E-03	--
Selenium	D	NA	--	NA	--	5.00E-03	a	NA	--	1.00E-03	Clinical selenosis
Silver	D	NA	--	NA	--	5.00E-03	a	NA	--	1.00E-03	Argyria
Sodium	NA	NA	--	NA	--	NA	--	NA	--	1.00E-03	--
Tetrachloroethene	C/B2	5.10E-02	--	2.03E-03	--	1.00E-02	a	NA	--	4.80E-02	Hepatoxicity in mice, weight gain in rats
Toluene	D	NA	--	NA	--	2.00E-01	a	1.14E-01	a	4.50E-02	Changes in liver and kidney weights
Trichloroethene	B2	1.12E-02	--	5.90E-03	--	6.00E-03	--	NA	--	1.60E-02	--
Vanadium	NA	NA	--	NA	--	7.00E-03	b	NA	--	1.00E-03	No adverse effects observed
Zinc	D	NA	--	NA	--	3.00E-01	a	NA	--	1.00E-03	47% decrease in erythrocyte superoxide dismutase concentration

[a] EPA, 1998b.
[b] EPA, 1997a.
[c] EPA, 1998d.
[d] EPA, 1992a.
NA = not available.

3.5.2.2 Reference Doses for Noncancer Effects

The toxicity value describing the dose-response relationship for noncancer effects is the reference dose value, or RfD. For noncarcinogenic effects, the body's protective mechanisms must be overcome before an adverse effect is manifested. If exposure is high enough and these protective mechanisms (or thresholds) are exceeded, adverse health effects can occur. EPA attempts to identify the upper bound of this tolerance range in the development of noncancer toxicity values. EPA uses the apparent toxic threshold value, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD. EPA defines an RfD as follows:

> In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of milligram per kilogram of body weight each day (mg/kg-day). (EPA, 1989)

This RA uses available chronic RfDs for the oral and inhalation exposure routes. Because EPA has derived no toxicity values specific to skin contact, oral RfDs are used for the dermal route. The RfDs for the COPCs identified for the Troutdale site are summarized in Table 3-6. A toxicological profile for fluoride is provided in Appendix D. The procedure for estimating risk using RfDs is described in Section 3.6.1.2.

3.5.2.3 Slope Factors for Cancer Effects

The dose-response relationship for cancer effects is expressed as a cancer slope factor that converts estimated intake directly to excess lifetime cancer risk. Slope factors are presented in units of risk per level of exposure (or intake). The data used to estimate the dose-response relationship are taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, since risk at low intake levels cannot be directly measured in animal or human epidemiological studies, a number of mathematical models and procedures have been developed to extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty. EPA assumes linearity at low doses and uses the linearized multistage procedure when uncertainty exists concerning the mechanism of action of a carcinogen and when information suggesting nonlinearity is absent.

It is assumed, therefore, that if a cancer response occurs at the dose levels used in the study, then there is some probability that a response will occur at all lower exposure levels (that is, a dose-response relationship with no threshold is assumed). Moreover, the dose-response slope chosen is usually the upper confidence limit on the dose-response curve observed in the laboratory studies. As a result, uncertainty and conservatism are built into EPA's risk extrapolation approach. EPA has stated that cancer risks estimated by this method "provide a rough but plausible upper limit of risk" (EPA, 1986). In other words, it is not likely that the true risk would be much more than the estimated risk, but "the true value of the risk is unknown and may be as low as zero" (EPA, 1986). The cancer slope factors used in this assessment are summarized in Table 3-6. The procedure for estimating risk using slope factors is described in Section 3.6.1.1.

3.6 Human Health Risk Characterization

This subsection summarizes the approach used to develop the human health risk estimates for groundwater at the Troutdale site and presents a quantitative risk characterization under the assumed exposure settings described in the exposure assessment section. In this risk characterization step, the results of the toxicity and exposure assessments are integrated to estimate the likelihood of potential adverse health effects.

As part of the area-specific risk evaluation, the resulting risk estimates are compared with EPA target risk criteria. Because DEQ target risk criteria are considered applicable or relevant and appropriate requirements (ARARs) for the RI/FS, a comparison is also made with these criteria. The EPA and DEQ target risk criteria are as follows:

- For EPA, target risk levels are exceeded when the total (multichemical) excess lifetime cancer risk exceeds 1 x 10^{-4} or the total noncancer hazard index exceeds 1.0 (EPA, 1991b).
- For DEQ, target risk levels are exceeded when the total (multichemical) excess lifetime cancer risk exceeds 1 x 10^{-5} (or 1 x 10^{-6} for a single carcinogen) or the total noncancer hazard index exceeds 1.0 (Oregon Administrative Rule 340-122). For chemicals with available drinking water maximum contaminant levels (MCLs), the MCL is considered the DEQ target limit in place of the risk-based limit and applies at relevant exposure points.

In this section, a risk characterization discussion is provided for the Tier 1 and Tier 2 RAs that includes the four exposure settings described in Section 2.4.

3.6.1 Quantification of Risk

Quantification of risk is accomplished by combining the results of the exposure assessment (estimated chemical intakes) with the results of the dose-response assessment (toxicity values established in the toxicity assessment) to provide numerical estimates of potential health effects. The quantification approach differs for potential noncancer and cancer effects, as described in the following subsections.

Although this baseline RA produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide EPA with information for use in risk management decisionmaking. Any actual risks are likely to be lower than these estimates, and they may even be zero. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates; as well as the magnitude of uncertainty surrounding them.

3.6.1.1 Cancer Risk Estimation Method

The potential for cancer effects is evaluated by estimating excess lifetime cancer risk. This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to site chemicals occurs). For example, a 2 x 10^{-6} excess lifetime cancer risk means that, for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by two cases of cancer. The background probability of developing cancer is about one in four (American Cancer Society, 1993). As previously mentioned, cancer slope factors developed by EPA represent upper-bound estimates, so any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than as accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA, 1989).

For the Troutdale site, excess lifetime cancer risks were estimated using the following formula:

$$Risk = 1 - \exp^{(-CDI \times SF)}$$

where:

Risk = Excess lifetime cancer risk (unitless probability)
CDI = Chronic daily intake averaged over a lifetime (mg/kg-day)
SF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$

Although synergistic or antagonistic interactions might occur between cancer-causing chemicals and other chemicals, information is generally lacking in the toxicological literature to quantify the effects of these potential interactions. Therefore, cancer risks are treated as additive within an exposure route in this assessment. This is consistent with the current EPA guidelines on chemical mixtures (EPA, 1986). For estimating cancer risks from exposure to multiple carcinogens from a single exposure route, the following equation is used:

$$Risk_T = \sum_1^N Risk_i$$

where:

$Risk_T$ = Total cancer risk from route of exposure
$Risk_i$ = Cancer risk for the i^{th} chemical
N = Number of chemicals

3.6.1.2 Noncancer Risk Estimation Method

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (that is, its RfD). The ratio of the chronic daily intake (CDI) divided by RfD is termed the hazard quotient (HQ):

$$HQ = {CDI}/{RfD}$$

When the HQ for a chemical exceeds 1.0 (that is, exposure exceeds RfD), there is a concern for potential noncancer health effects. To assess the potential for noncancer effects posed by exposure to multiple chemicals, a "hazard index" approach was used according to EPA guidance (EPA, 1986). This approach assumes that the noncancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not accounted for. The hazard index may exceed 1.0 even if all the individual hazard quotients are less than 1.0. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate hazard indexes may then be derived based on mechanism and effect. The hazard index is calculated as follows:

$$HI = \sum\left(CDI_i / RfD_i \right)$$

where:

HI	=	Hazard index
CDI_i	=	Chronic daily intake of the i^{th} chemical (mg/kg-day)
RfD_i	=	Reference dose of the i^{th} chemical (mg/kg-day)
N	=	Number of chemicals

3.6.2 Tier 1 Risk Assessment

The Tier 1 RA consists of a well-specific RA that serves to identify which of the 18 selected COPCs present in sitewide groundwater (at any location or hydrogeologic zone) exist at concentrations that could feasibly pose risk at relevant exposure points (that is, where drinking wells are currently placed or could reasonably be placed in the future) and should be carried into Tier 2. Maximum groundwater concentrations measured in individual wells from the four most recent sampling events were used to estimate well-specific risks from groundwater ingestion. Any chemicals in any individual sitewide monitoring well with concentrations exceeding an excess lifetime cancer risk of 1 x 10^{-6} or a hazard quotient of 1.0 are selected to be carried forward to the Tier 2 RA. COPCs with maximum concentrations below these target risk levels are not feasibly expected to pose unacceptable risk at the selected Tier 2 exposure points (see Section 3.4.5.2). It should be emphasized that Tier 1 does not provide actual risk estimates for monitoring wells, but only serves to prioritize and identify constituents to be evaluated during Tier 2.

The results for both occupational and residential scenarios are included in this Tier 1 RA. Although the occupational worker is the most likely future receptor at RMC-Troutdale, the results obtained from residential exposures were used to select constituents to address in the Tier 2 RA, as recommended by EPA. The results from the residential Tier 1 RA provide a conservative identification of these constituents based on the more conservative exposure assumptions used for the residential scenario. Exposure assumptions for the Tier 1 RA are summarized in Section 3.4.

Only locations with measurable COPC concentrations were evaluated during Tier 1. Because MRLs during the RI were adequate for meeting risk-based levels, chemicals that were not detected in groundwater were not carried forward into the Tier 2 RA. The following subsections describe the results of the Tier 1 RA.

3.6.2.1 Tier 1 Results

The results of Tier 1 indicated that, of the 18 sitewide COPCs identified for groundwater, the following eight constituents exist at maximum concentrations that could feasibly pose risk at relevant exposure points and were carried forward into the Tier 2 HHRA:

- 1,1-Dichloroethene (1,1-DCE)

- 1,2-Dichloroethane (1,2-DCA)
- Arsenic
- Cyanide
- Fluoride
- Iron
- Manganese
- Tetrachloroethene (PCE)

Evaluation of Excess Lifetime Cancer Risk. Of the 18 COPCs identified in groundwater (Section 3.3), arsenic, 1,1-dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), and tetrachloroethene (PCE) have been identified by EPA as known or suspected carcinogens. Of the 90 well locations that were evaluated during the Tier 1 RA, 25 well locations were reported with measurable concentrations of at least one of these COPCs exceeding the excess lifetime cancer risk (ELCR) criterion of 10^{-6}. Table 3-7 presents a summary of detected chemical concentrations in groundwater exceeding an individual ELCR of 10^{-6}.

1,2-DCA was detected at one well location at a concentration that exceeded an individual ELCR of 10^{-6}. Arsenic was measured at 19 well locations at concentrations that exceed an individual ELCR of 10^{-6}; 1,1-DCE and PCE were measured at three well locations at concentrations that exceed an individual ELCR of 10^{-6}. Therefore, arsenic, 1,2-DCA, 1,1-DCE, and PCE were carried forward to the Tier 2 RA.

Evaluation of Noncancer Risks. Of the 18 COPCs identified in groundwater at RMC, 16 have available RfDs. Of the 90 well locations that were evaluated during the Tier 1 RA, 41 wells were reported with COPC concentrations that exceed a hazard quotient (HQ) of 1.0. From these 41 wells, arsenic, cyanide, fluoride, iron, manganese, and PCE are the only chemicals that exceed an HQ of 1.0, as highlighted in Table 3-8. These six COPCs were carried forward to the Tier 2 RA.

In order of frequency of occurrence, chemicals at concentrations exceeding an individual HQ of 1.0 included fluoride at 24 well locations; iron at 15 locations; manganese at five well locations; arsenic at two well locations; total cyanide at two well locations; and PCE at one well location.

Aluminum, antimony, barium, beryllium, cadmium, copper, cyanide, naphthalene, nickel, and vanadium were COPCs measured at concentrations that did not exceed an individual HQ of 1.0 at any well location; therefore, these chemicals were not carried forward to the Tier 2 RA.

Lead Characterization Results. The Tier 1 RA compared the 95 percent UCL concentration of lead in groundwater with EPA's drinking water action level to determine whether it is to be carried forward into the Tier 2 RA. The 95 percent UCL concentration for lead in groundwater, calculated using the four most recent sampling events from individual well locations, is 0.002 milligram per liter (mg/L) and is below the drinking water action level of 0.015 mg/L. Lead is not considered to be a health concern, therefore, and was not carried forward into the Tier 2 RA.

Table 3-7
Tier 1 Well-Specific Risk Results
COPCs Detected in Individual Wells at Levels Exceeding an ELCR of 10^{-6}
Occupational and Residential Exposure Scenarios

Rank[a]	Station ID	Collection Date	Occupational Total ELCR	Residential Total ELCR	Chemical	Concentration (mg/L)	Q	Occupational Chemical-Specific ELCR	Residential Chemical-Specific ELCR	Risk Contrib. (%)
1	MW11-017	08/21/97	5.76E-04	1.94E-03	Arsenic	0.1100		5.76E-04	1.94E-03	100.0
2	MW36-006	11/04/97	9.43E-05	3.17E-04	Arsenic	0.0180		9.43E-05	3.17E-04	100.0
3	MW32-040	08/12/98	6.82E-05	2.29E-04	1,1-Dichloroethene	0.0010		2.10E-06	7.04E-06	3.1
3	MW32-040	08/12/98	6.82E-05	2.29E-04	Tetrachloroethene	0.3700	D	6.59E-05	2.22E-04	96.7
4	MW33-095	11/06/97	4.97E-05	1.67E-04	Arsenic	0.0095		4.97E-05	1.67E-04	100.0
5	MW13-022	08/20/97	4.92E-05	1.65E-04	Arsenic	0.0094		4.92E-05	1.65E-04	100.0
6	MW45-042	11/07/97	4.51E-05	1.51E-04	Arsenic	0.0086		4.51E-05	1.51E-04	100.0
7	MW33-033	11/06/97	4.03E-05	1.35E-04	Arsenic	0.0077		4.03E-05	1.35E-04	100.0
8	MW03-098	08/14/98	3.61E-05	1.21E-04	Arsenic	0.0069		3.61E-05	1.21E-04	100.0
9	MW37-030	08/25/97	3.32E-05	1.12E-04	Arsenic	0.0061		3.19E-05	1.07E-04	96.1
10	MW12-092	11/06/97	2.93E-05	9.84E-05	Arsenic	0.0056		2.93E-05	9.84E-05	100.0
11	MW29-033	02/20/97	2.80E-05	9.40E-05	Arsenic	0.0051		2.67E-05	8.96E-05	95.4
12	MW48-165	02/18/98	2.75E-05	9.22E-05	Arsenic	0.0050		2.62E-05	8.79E-05	95.3
13	MW39-095	08/14/98	2.73E-05	9.16E-05	Arsenic	0.0052		2.73E-05	9.16E-05	100.0
14	MW47-094	11/11/97	2.73E-05	9.16E-05	Arsenic	0.0052		2.73E-05	9.16E-05	100.0
15	MW18-031	08/08/96	2.62E-05	8.79E-05	Arsenic	0.0050		2.62E-05	8.79E-05	100.0
16	MW35-038	11/07/97	2.57E-05	8.63E-05	Arsenic	0.0049		2.57E-05	8.63E-05	100.0
17	MW25-035	02/20/97	2.48E-05	8.34E-05	Arsenic	0.0045		2.35E-05	7.91E-05	94.8
18	MW02-034	05/15/96	2.46E-05	8.26E-05	Arsenic	0.0047		2.46E-05	8.26E-05	100.0
19	MW49-095	08/17/98	2.20E-05	7.38E-05	Arsenic	0.0042		2.20E-05	7.38E-05	100.0
20	MW15-086	02/16/98	2.10E-05	7.04E-05	Arsenic	0.0040		2.10E-05	7.04E-05	100.0
21	MW48-055	11/19/97	1.49E-05	5.01E-05	1,1-Dichloroethene	0.0020		4.19E-06	1.41E-05	28.1
22	MW50-094	11/19/97	1.23E-05	4.12E-05	1,2-Dichloroethane	0.0020		6.36E-07	2.14E-06	5.2
23	MW16-014	02/18/97	1.22E-05	4.11E-05	Tetrachloroethene	0.0030		5.35E-07	1.80E-06	4.4
24	MW03-175	08/22/97	1.18E-05	3.96E-05	1,1-Dichloroethene	0.0005		1.05E-06	3.52E-06	8.9
25	MW41-033	02/17/98	1.56E-06	5.25E-06	Tetrachloroethene	0.0020		3.56E-07	1.20E-06	22.8

[a] Rank of individual wells from highest to lowest ELCR.

Shading indicates that chemical-specific ELCR exceeds 1 x 10^{-6}.

Table 3-8
Tier 1 Well-Specific Risk Results
COPCs Detected in Individual Wells at Levels Exceeding an HQ of 1.0
Occupational and Residential Exposure Scenarios

Rank[a]	Station ID	Collection Date	Occupational HI	Residential HI	Chemical	Concentration (mg/L)	Q	Occupational HQ	Residental HQ	HI Contrib. (%)
1	MW11-017	17-Aug-98	7.32E+01	2.05E+02	Arsenic	0.07999		2.61	7.31	3.57
1	MW11-017	17-Aug-98	7.32E+01	2.05E+02	Fluoride	432		70.45	197.26	96.29
2	MW04-019	06-Aug-96	3.42E+01	9.58E+01	Arsenic	0.016		0.52	1.46	1.52
2	MW04-019	06-Aug-96	3.42E+01	9.58E+01	Iron	18.4		0.60	1.68	1.75
2	MW04-019	06-Aug-96	3.42E+01	9.58E+01	Fluoride	200		32.62	91.32	95.31
3	MW13-022	17-Aug-98	1.98E+01	5.54E+01	Fluoride	119		19.41	54.34	98.10
4	MW36-006	06-Nov-97	1.96E+01	5.48E+01	Fluoride	120		19.57	54.79	100.00
5	MW33-095	06-Nov-97	1.91E+01	5.36E+01	Fluoride	112		18.26	51.14	95.40
6	MW26-012	21-Aug-97	1.77E+01	4.96E+01	Fluoride	104		16.96	47.49	95.83
7	MW21-012	20-Nov-96	1.39E+01	3.89E+01	Fluoride	60.5		9.87	27.63	71.03
7	MW21-012	20-Nov-96	1.39E+01	3.89E+01	Iron	113		3.69	10.32	26.53
8	MW19-013	19-Feb-97	8.51E+00	2.38E+01	Fluoride	50.3		8.20	22.97	96.39
9	MW01-019	06-Aug-96	5.82E+00	1.63E+01	Fluoride	33		5.38	0.39	<0.01
10	MW02-012	07-Aug-96	5.15E+00	1.44E+01	Fluoride	30	D	4.89	13.70	95.07
11	MW02-024	11-May-95	4.62E+00	1.29E+01	Fluoride	27		4.40	12.33	95.41
12	MW25-024	20-Feb-97	4.50E+00	1.26E+01	Fluoride	26.6	J	4.34	12.15	96.38
13	MW37-030	20-Feb-97	4.14E+00	1.16E+01	Iron	67.6		2.20	6.17	53.32
13	MW37-030	20-Feb-97	4.14E+00	1.16E+01	Manganese	7.17		1.50	4.21	36.33
14	MW16-014	18-Feb-97	3.91E+00	1.09E+01	Fluoride	22.9		3.73	10.46	95.61
15	MW23-025	19-Feb-97	3.11E+00	8.69E+00	Fluoride	18.2		2.97	8.31	95.58
16	MW06-094	20-Feb-97	2.76E+00	7.73E+00	Fluoride	13.4	J	2.19	6.12	79.20
17	MW24-010	24-Feb-97	2.74E+00	7.66E+00	Fluoride	15.9		2.59	7.26	94.77
18	MW21-025	18-Feb-97	2.25E+00	6.31E+00	Fluoride	12.6		2.05	5.75	91.23
19	MW18-016	08-Aug-96	2.21E+00	6.17E+00	Iron	26.6		0.87	2.43	39.34
19	MW18-016	08-Aug-96	2.21E+00	6.17E+00	Fluoride	7.1		1.16	3.24	52.50
20	MW37-012	20-Feb-97	2.19E+00	6.12E+00	Fluoride	3.57	J	0.58	1.63	26.62
20	MW37-012	20-Feb-97	2.19E+00	6.12E+00	Iron	38.1		1.24	3.48	56.81
21	MW50-094	19-Nov-97	1.79E+00	5.01E+00	Iron	27.4		0.89	2.50	49.98

Table 3-8
Tier 1 Well-Specific Risk Results
COPCs Detected in Individual Wells at Levels Exceeding an HQ of 1.0
Occupational and Residential Exposure Scenarios

Rank[a]	Station ID	Collection Date	Occupational HI	Residential HI	Chemical	Concentration (mg/L)	Q	Occupational HQ	Residental HQ	HI Contrib. (%)
21	MW50-094	19-Nov-97	1.79E+00	5.01E+00	Manganese	3.27		0.69	1.92	38.32
22	MW18-031	18-Feb-97	1.51E+00	4.22E+00	Manganese	4.63		0.97	2.72	64.36
23	MW02-034	24-Feb-97	1.49E+00	4.17E+00	Fluoride	6.69		1.09	3.05	73.18
24	MW48-165	19-Nov-97	1.40E+00	3.93E+00	Fluoride	6.63		1.08	3.03	77.10
25	MW14-015	07-Aug-96	1.22E+00	3.43E+00	Fluoride	6.3		1.03	2.88	83.99
26	MW15-086	10-Nov-97	1.17E+00	3.27E+00	Iron	30.2		0.98	2.76	84.43
27	MW51-069	10-Aug-98	1.16E+00	3.25E+00	Iron	26.8		0.87	2.45	75.26
28	MW10-090	10-Nov-97	1.07E+00	2.99E+00	Iron	27.1		0.88	2.47	82.83
29	MW30-100	05-Nov-97	<1.00E+00	2.56E+00	Iron	22			2.01	78.62
30	MW33-165	06-Nov-97	<1.00E+00	2.50E+00	Cyanide, Total	1.17			1.60	64.17
31	MW21-063	18-Feb-97	<1.00E+00	2.32E+00	Iron	15.7			1.43	61.67
32	MW33-033	25-Feb-97	<1.00E+00	2.26E+00	Manganese	1.71			1.00	44.35
33	MW08-027	17-Feb-97	<1.00E+00	2.24E+00	Fluoride	3.75			1.71	76.33
34	MW34-038	06-Nov-97	<1.00E+00	2.08E+00	Cyanide, Total	0.944			1.29	62.30
35	MW12-021	06-Nov-97	<1.00E+00	2.03E+00	Iron	16.7			1.53	75.14
36	MW49-145	18-Nov-97	<1.00E+00	1.97E+00	Manganese	2			1.17	59.45
37	MW17-028	22-Aug-97	<1.00E+00	1.90E+00	Iron	17.7			1.62	85.26
38	MW53-034	10-Aug-98	<1.00E+00	1.86E+00	Iron	13.1			1.20	64.42
39	MW20-026	18-Feb-97	<1.00E+00	1.83E+00	Fluoride	3.36			1.53	84.07
40	MW38-035	07-Nov-97	<1.00E+00	1.58E+00	Iron	11.8			1.08	68.02
41	MW32-040	12-Aug-98	<1.00E+00	1.30E+00	Tetrachloroethene	0.37	D		1.01	77.99

[a] Rank of individual wells from highest to lowest ELCR.
Shading indicates that chemical-specific HQ exceeds 1.0 .

Additional Evaluation of Arsenic, Iron, and Manganese. Three of the eight COPCs identified to be carried forward into Tier 2 (arsenic, iron, and manganese) were evaluated to determine whether their presence in groundwater is naturally occurring or the result of historical site releases. The hypothesis for this evaluation was that if these metals originated from site releases, they would likely co-occur with fluoride in groundwater. Using regression analysis, a strong spatial association between elevated fluoride concentrations and elevated concentrations of these metals (as indicated by an R^2 value close to 1.0) would suggest they result from co-releases at RMC. The results of these comparisons, presented in Appendix B, are depicted as scatter plots plotting fluoride concentrations against arsenic, iron, and manganese concentrations measured in synoptic samples.

The regression analyses conducted on these data indicated a low correlation between fluoride and iron ($R^2= 0.24$) or fluoride and manganese ($R^2= 0.005$) in groundwater. For arsenic, however, the spatial association with fluoride was relatively high ($R^2= 0.85$). These results suggest that iron and manganese concentrations are not the result of co-releases with fluoride at RMC, but likely represent natural variability in groundwater. At EPA's request, however, arsenic, iron, and manganese were all carried forward into the Tier 2 RA.

3.6.3 Tier 2 Risk Assessment

The Tier 2 RA uses site-specific information to provide more realistic exposure estimates for the eight most important COPCs identified during Tier 1. Exposure settings and exposure points (see Section 3.4) were selected based on discussions with EPA and DEQ during the RI, and are consistent with current and reasonably anticipated future land uses.

As discussed in the conceptual exposure model (Section 2), workers are the most probable receptor for groundwater use onsite at RMC-Troutdale and offsite at Sundial Marine Tug & Barge and Gresham Sand & Gravel under both current and future land use conditions. Because land use at Fairview Farms is zoned for both HM and UF-20 (Section 2.2), it is possible that residential homes could be built in the area of Fairview Farms in the future. Therefore, residents are also considered a potential receptor under future offsite land use conditions.

For all exposure settings, potential health risks from chemical concentrations in groundwater were evaluated for ingestion, dermal contact, and inhalation (VOCs only) routes of potential exposure. This assumes that current and future groundwater users consume groundwater, and also use it for showering at work and home (Fairview Farms). Upper-bound exposure assumptions are used to estimate reasonable maximum exposure (RME) conditions to provide a bounding estimate on exposure. In cases where RME risks exceed EPA risk criteria (risk > 10^{-4}, HI > 1.0), more typical or average-case exposure parameters are also used to help account for some of the uncertainties resulting from the use of RME assumptions. The exposure parameters used to generate RME or average-case risk estimates under both current and future land use conditions are as listed in Table 3-4.

3.6.3.1 Tier 2 Results

This section provides the Tier 2 risk estimates for the four groundwater exposure settings identified for the Troutdale site. The cancer and noncancer risk estimates for onsite and offsite exposure points, under current and future site conditions, are summarized in

Table 3-9. The results are listed by exposure route, as well as the total multi-route risk estimates.

Table 3-9
Summary of Tier 2 Risk Estimates for Current and Future Exposure to Groundwater

		Average Exposure		Reasonable Maximum Exposure	
Exposure Scenario	**Exposure Route**	**Noncancer Hazard Index**	**Excess Lifetime Cancer Risk**	**Noncancer Hazard Index**	**Excess Lifetime Cancer Risk**
Current Onsite Occupational Worker	Ingestion	N/C	N/C	0.26	N/A
	Dermal	N/C	N/C	0.001	N/A
	Inhalation	N/C	N/C	N/A	N/A
	Total	N/C	N/C	0.26	N/A
Future Onsite Occupational Worker	Ingestion	N/C	N/C	0.34	9×10^{-7}
	Dermal	N/C	N/C	0.002	2×10^{-7}
	Inhalation	N/C	N/C	N/A	5×10^{-6}
	Total	N/C	N/C	0.34	6×10^{-6}
Current Offsite Occupational Worker	Ingestion	N/C	N/C	0.057	N/A
	Dermal	N/C	N/C	0.0003	N/A
	Inhalation	N/C	N/C	N/A	N/A
	Total	N/C	N/C	0.06	N/A
Future Offsite Occupational Worker	Ingestion	N/C	N/C	0.95	N/A
	Dermal	N/C	N/C	0.004	N/A
	Inhalation	N/C	N/C	N/A	N/A
	Total	N/C	N/C	0.95	N/A
Future Offsite Residential	Ingestion	1.8	N/C	3.2	N/A
	Dermal	0.004	N/C	0.007	N/A
	Inhalation	NA	N/C	NA	N/A
	Total	**1.8**	N/C	**3.2**	N/A

N/C = Not calculated; the average case risk estimates were calculated only when the RME case estimates exceeded EPA target risk levels [$>10^{-4}$ ELCR; >1.0 hazard index (HI)].
N/A = Exposure is incomplete for this exposure route.

These results indicate that, of the four settings evaluated, the future offsite residential (but not occupational) water use setting results in noncancer risks exceeding EPA's target risk level of HQ>1.0. The estimated future offsite fluoride concentrations also exceed DEQ's target, the MCL of 4 mg/L. All other exposure settings result in risk estimates below regulatory limits. Discussion of the Tier 2 risk estimates for each exposure setting is provided below. Appendix E provides the individual risk calculation data sheets used to develop the risk summaries.

Current Onsite Water Use. The eight COPCs carried forward from Tier 1 were evaluated to determine whether potential risks may be posed under current onsite water use conditions at RMC. Table 3-10 provides a summary of the data sources used to evaluate these constituents, and provides the rationale for inclusion or exclusion from the Tier 2 risk calculations for this exposure setting. The EPCs for these constituents were estimated using the hierarchy described in Section 3.4.3.2.

Fluoride concentrations measured in tap water at the plant are considered representative of current onsite use and were used to calculate the EPC for this constituent. Fluoride concentrations were measured at the tap three times per week (a total of 154 measurements) for the past year (May 1998 through April 1999); these data are provided in Table 3-11. On the basis of these data, the EPC for fluoride, calculated as the 95 percent UCL of the mean concentration, is 1.51 mg/L.

Concentrations of arsenic, cyanide, iron, manganese, and the volatile organic compounds (VOCs) (1,1-DCE, 1,2-DCA, and PCE) measured in recently active production wells PW03, PW07, PW08, PW10, and PW18 are considered representative of current onsite use. A summary of analytical results for arsenic, cyanide, iron, manganese, and VOC concentrations in the recently active production wells is presented in Table 3-12.

Arsenic and VOCs were not detected in any of the five recently active production wells in any analyses between December 1993 and December 1997 (a total of 27 sampling rounds for arsenic, 15 sampling rounds for VOCs); therefore, these COPCs were not included in the Tier 2 risk calculation for this exposure setting. Cyanide was detected 10 of 27 analyses and is included in the Tier 2 analysis. Iron and manganese were detected at maximum concentrations of 2.05 and 0.66 mg/L, respectively. Because these levels are within the range of naturally occurring local background (maximum of 7.1 mg/L for iron and 0.66 mg/L for manganese), these two metals were also not included in the Tier 2 risk calculation for this setting.

For current onsite groundwater usage, the following assumptions are used to estimate potential RME for an occupational scenario:

- A 70-kilogram (kg) occupational worker is assumed to work full-time at the RMC facility, 250 days per year over 25 years of employment, consuming 1 liter of drinking water per day and showering for 15 minutes per day at the plant.

Tier 2 risk estimates for current occupational workers are summarized in Table 3-9. These results indicate that the HQs for chemicals detected in groundwater, as well as the total hazard index (HI), are well below the EPA and DEQ target risk levels of 1.0. The primary contributor to noncancer risk is fluoride (95 percent). The current onsite exposure assumptions and risk calculation data tables are provided in Appendix E, Tables E-1 through E-8.

Future Onsite Water Use. The eight COPCs carried forward from Tier 1 were evaluated to determine whether potential risks may be posed under future onsite water use conditions at RMC. Table 3-13 provides a summary of the data sources used to evaluate these constituents, and provides the rationale for inclusion or exclusion from the Tier 2 risk calculations for this exposure setting. The EPCs for these constituents were estimated using the

Table 3-10
Tier 2 Exposure Point Concentration Estimates for Current Onsite Groundwater

Chemical	Data Source	Number of Samples	Result (mg/L)	Addressed in Tier 2
Fluoride	95%UCL onsite tap	154	1.51	yes
Cyanide	95%UCL onsite production wells[a]	17	0.025	yes
Arsenic	95%UCL onsite production wells	17	<0.005	no[b]
Iron	95%UCL onsite production wells	16	2.05	no[c]
Manganese	95%UCL onsite production wells	12	0.66	no[c]
1,1-DCE	95%UCL onsite production wells	15	<0.0005	no[b]
1,2-DCA	95%UCL onsite production wells	15	<0.0005	no[b]
PCE	95%UCL onsite production wells	15	<0.0005	no[b]

[a] Includes data from four most current sampling rounds from recently active onsite production wells PW03, PW07, PW08, PW10, and PW18.

[b] Not included in the risk calculation for current onsite water use setting because this chemical was not detected in recently active production wells.

[c] Not included in the risk calculation for current onsite water use setting because the maximum detect for this chemical was not above maximum background levels of 7.08 mg/L for iron and 0.66 mg/L for manganese.

Table 3-11
Summary of Fluoride Concentrations Measured in Tap Water
Current Onsite Exposure Point Concentration--Fluoride

Date	Fluoride (mg/L)	Date	Fluoride (mg/L)	Date	Fluoride (mg/L)	Date	Fluoride (mg/L)
01-May-98	0.59	31-Jul-98	1.98	30-Oct-98	1.73	29-Jan-99	1.23
04-May-98	2.12	03-Aug-98	1.90	02-Nov-98	0.88	01-Feb-99	1.03
06-May-98	2.32	05-Aug-98	2.28	04-Nov-98	1.24	03-Feb-99	1.06
08-May-98	2.32	07-Aug-98	2.20	06-Nov-98	1.15	05-Feb-99	1.10
12-May-98	2.33	10-Aug-98	1.78	10-Nov-98	0.66	08-Feb-99	1.19
13-May-98	2.15	12-Aug-98	2.28	11-Nov-98	0.77	10-Feb-99	0.62
15-May-98	2.27	14-Aug-98	2.28	13-Nov-98	2.23	12-Feb-99	1.32
18-May-98	1.76	18-Aug-98	2.19	16-Nov-98	2.00	16-Feb-99	1.26
20-May-98	1.80	19-Aug-98	2.18	18-Nov-98	1.88	17-Feb-99	1.17
22-May-98	1.72	21-Aug-98	2.12	20-Nov-98	1.98	19-Feb-99	1.04
26-May-98	1.72	24-Aug-98	2.02	23-Nov-98	1.73	22-Feb-99	1.15
27-May-98	1.81	26-Aug-98	2.47	24-Nov-98	2.00	24-Feb-99	1.05
29-May-98	1.75	28-Aug-98	2.17	25-Nov-98	1.92	26-Feb-99	1.06
01-Jun-98	1.90	31-Aug-98	2.13	30-Nov-98	1.55	01-Mar-99	1.37
03-Jun-98	1.86	02-Sep-98	2.02	02-Dec-98	1.79	03-Mar-99	0.98
05-Jun-98	1.65	04-Sep-98	2.36	04-Dec-98	1.95	05-Mar-99	1.03
08-Jun-98	1.82	09-Sep-98	0.68	07-Dec-98	1.70	08-Mar-99	1.03
10-Jun-98	2.02	10-Sep-98	1.06	09-Dec-98	1.59	10-Mar-99	1.15
12-Jun-98	1.84	11-Sep-98	0.64	11-Dec-98	1.89	12-Mar-99	1.10
15-Jun-98	1.88	15-Sep-98	0.47	14-Dec-98	1.46	15-Mar-99	1.23
17-Jun-98	1.95	16-Sep-98	0.49	16-Dec-98	1.38	17-Mar-99	1.26
19-Jun-98	1.98	18-Sep-98	0.59	18-Dec-98	1.77	19-Mar-99	1.11
22-Jun-98	2.45	21-Sep-98	0.65	21-Dec-98	0.84	22-Mar-99	1.22
24-Jun-98	2.00	23-Sep-98	0.64	22-Dec-98	0.88	24-Mar-99	1.15
26-Jun-98	1.92	25-Sep-98	0.60	23-Dec-98	1.56	26-Mar-99	1.28
30-Jun-98	1.91	29-Sep-98	0.75	29-Dec-98	0.88	30-Mar-99	1.08
01-Jul-98	2.03	30-Sep-98	0.48	30-Dec-98	0.69	31-Mar-99	1.11
03-Jul-98	1.91	02-Oct-98	0.48	31-Dec-98	1.08	01-Apr-99	1.04
06-Jul-98	1.79	05-Oct-98	0.68	05-Jan-99	1.26	05-Apr-99	1.16
08-Jul-98	2.03	07-Oct-98	0.95	06-Jan-99	1.14	07-Apr-99	1.27
10-Jul-98	1.89	09-Oct-98	0.52	08-Jan-99	1.09	09-Apr-99	1.31
13-Jul-98	2.15	12-Oct-98	0.65	11-Jan-99	1.28	12-Apr-99	1.12
15-Jul-98	2.26	14-Oct-98	0.53	13-Jan-99	1.15	14-Apr-99	1.06
17-Jul-98	1.97	16-Oct-98	1.03	15-Jan-99	1.10	16-Apr-99	1.22
20-Jul-98	1.71	19-Oct-98	0.86	19-Jan-99	1.06	20-Apr-99	1.06
22-Jul-98	1.72	21-Oct-98	0.76	20-Jan-99	1.02	21-Apr-99	1.23
24-Jul-98	1.98	23-Oct-98	1.19	22-Jan-99	1.09	23-Apr-99	1.20
27-Jul-98	2.07	26-Oct-98	0.93	25-Jan-99	1.24		
29-Jul-98	1.95	28-Oct-98	0.94	27-Jan-99	1.10		

Table 3-12
Summary of COPC Concentrations Measured in Production Wells
Current Onsite Exposure Point Concentration

Well ID	Date Collected	1,1-DCE		1,2-DCA		PCE		Arsenic		Cyanide		Iron	Manganese
PW03	12/9/93	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01	U		
PW03	3/29/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01		0.23	0.26
PW03	6/28/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01	U	0.23	0.26
PW03	8/16/94							0.004	U	0.01	U	0.23	0.26
PW03	12/13/97	0.0005	U	0.0005	U	0.0005	U	0.050	U	0.02			
PW07	8/16/94							0.004	U	0.01	U	0.25	0.16
PW07	12/13/97	0.0005	U	0.0005	U	0.0005	U						
PW08	12/9/93	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.03			
PW08	3/29/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.02			
PW08	6/28/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01	U		
PW08	8/16/94											1.80	0.63
PW08	2/8/95											2.00	
PW08	5/10/95							0.004	U	0.02	U		0.66
PW08	8/11/95							0.004	U	0.02	U		
PW08	12/8/95							0.004	U	0.02	L	2.05	
PW08	2/9/96							0.004	U	0.02	UL	1.88	
PW10	12/9/93	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01	U		
PW10	3/29/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01	U		
PW10	6/28/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.01	U		
PW10	8/16/94												0.12
PW10	5/10/95												0.13
PW10	8/9/96							0.004	U	0.02	U	0.18	
PW10	11/22/96							0.001	U	0.01	U	0.18	
PW10	2/26/97							0.004	U	0.01	UJ	0.22	0.12
PW10	8/28/97							0.004	U	0.02	U	0.25	
PW10	12/13/97	0.0005	U	0.0005	U	0.0005	U						
PW18	12/9/93	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.03			
PW18	3/29/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.05			
PW18	6/28/94	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.03			
PW18	8/16/94												0.42
PW18	5/10/95												0.37
PW18	8/9/96							0.004	U	0.02		1.40	
PW18	11/22/96							0.003	U	0.01	U	1.21	
PW18	2/26/97							0.004	U	0.01	J	1.42	0.34
PW18	8/28/97							0.004	U	0.02	U	1.46	

Notes:
Concentrations represent most current four rounds of analyses available for each constituent.
U = Not detected at specified detection limit.

Table 3-13
Tier 2 Exposure Point Concentration Estimates for Future Onsite Groundwater

Chemical	Data Source	Number Samples	Result (mg/L)	Addressed in Tier 2
Fluoride	95%UCL PW08 (5/98-4/99)[a]	12	1.99	yes
Cyanide	95%UCL PW08 (5/98-4/99)	12	0.022	yes
Arsenic	95%UCL MW11[b]/mixing factor (47)	11	0.003	no[d]
Iron	95%UCL onsite[c]/mixing factor (47)	203	0.22	no[d]
Manganese	95%UCL onsite/mixing factor (47)	57	0.021	no[d]
1,1-DCE	(95%UCL MW32,33,48)[e]/mixing factor (47)	9	0.00005	yes
1,2-DCA	Detected only once out of 92 samples	92	0.002	no[f]
PCE	(95%UCL MW16,32,33,41, 48)/mixing factor (47)	11	0.0042	yes

[a] Includes data from sampling rounds after 1998 plant startup, from PW08.

[b] Includes data from the only well with MCL exceedances for arsenic, in MW11.

[c] Includes data from the most current four sampling rounds for all onsite monitoring wells.

[d] Not included in the risk calculation for future onsite water use setting because the estimated exposure concentration for this chemical was not above maximum background levels of 0.007 mg/L for arsenic, 7.08 mg/L for iron, and 0.66 mg/L for manganese.

[e] Data for VOCs conservatively include only detects from all wells where these chemicals were present during the RI.

[f] Not included in the risk calculation for future onsite water use setting because of low detection frequency and concentration.

hierarchy described in Section 3.4.3.2. The data used to derive the EPCs are presented in Table 3-14.

To estimate future onsite tap water concentrations, it was assumed that onsite water use would be reduced to nominal industrial conditions, such that groundwater would be obtained from only one production well (PW08). In addition, PW08 was selected to predict "worst-case" future chemical exposure concentrations at the property. Current fluoride and cyanide concentrations measured at PW08 are considered representative of future onsite use and were used to calculate the EPCs. Fluoride and cyanide concentrations at PW08 were measured at an approximate frequency of once per month (a total of 12 measurements) for the past year (May 1998 through April 1999). The EPCs for fluoride and cyanide, calculated as the 95 percent UCL of the mean concentration, are 1.99 and 0.022 mg/L, respectively. A summary of the fluoride and cyanide concentrations measured at PW08 between May 1998 and April 1999 is presented in Table 3-14. These two constituents are included in the Tier 2 risk calculations for this exposure setting.

The EPC for arsenic was calculated by dividing the 95 percent UCL concentration from MW11-017 (containing the maximum sitewide detections of arsenic) by the mixing factor of 47 derived in Section 3.4.3.2. Arsenic concentrations measured at MW11-017 between August 1994 and August 1998 were selected to represent an upper bound on future onsite conditions because MW11-017 is the only onsite location with arsenic concentrations above the MCL (greater than 0.05 mg/L). A spatial association has been observed between arsenic and fluoride in sitewide groundwater (see scatter plot analysis in Appendix B). A summary of arsenic concentrations measured in MW11-017 is presented in Table 3-14. The EPC was calculated as follows:

$$EPC_{arsenic} = \frac{0.14\ mg/L}{47} = 0.003\ mg/L$$

Because the estimated EPC for arsenic is in the range of concentrations measured in local background (mean 0.003 mg/L; maximum 0.007 mg/L), this metal was not included in the Tier 2 risk calculation for this setting.

The EPCs for 1,1-DCE and PCE were calculated by dividing the 95 percent UCL concentrations by the mixing factor of 47 derived in Section 3.4.3.2. As a conservative estimate, the 95 percent UCL concentrations were derived using only detectable concentrations measured at individual monitoring wells from the four most recent sampling events. Summaries of 1,1-DCE and PCE concentrations measured at individual monitoring wells from the four most recent sampling rounds are presented in Table 3-14. These two constituents are included in the Tier 2 risk calculations for this exposure setting. The EPCs were calculated as follows:

$$EPC_{1,1\text{-}DCE} = \frac{0.0023\ mg/L}{47} = 0.000049\ mg/L$$

$$EPC_{PCE} = \frac{0.196\ mg/L}{47} = 0.0042\ mg/L$$

Table 3-14
Analytical Data Used to Derive Future Onsite Exposure Point Concentrations

Station	Date	Fluoride (mg/L)	Station	Date	Cyanide (mg/L)	Station	Date	Arsenic (mg/L)	Station	Date	1,1-DCE (mg/L)	Station	Date	PCE (mg/L)
PW08	5/12/98	2.10	PW08	5/12/98	0.02644	MW11	08/17/98	0.07999	MW32	2/17/98	0.003	MW16	2/18/97	0.003
PW08	6/18/98	2.12	PW08	6/18/98	0.03231	MW11	02/16/98	0.092	MW32	8/12/98	0.001	MW16	5/16/97	0.001
PW08	7/16/98	1.99	PW08	7/16/98	0.00612	MW11	05/11/95	0.0993	MW32	8/25/97	0.004	MW32	8/25/97	0.4
PW08	8/16/98	2.16	PW08	8/16/98	0.01542	MW11	08/21/97	0.10999	MW33	2/17/98	0.0008	MW32	2/17/98	0.37
PW08	9/22/98	2.30	PW08	9/22/98	0.01564	MW11	02/25/97	0.114	MW33	8/11/98	0.0003	MW32	8/12/98	0.34
PW08	10/22/98	2.16	PW08	10/22/98	0.01232	MW11	02/13/96	0.115	MW33	8/25/97	0.001	MW33	2/17/98	0.0002
PW08	11/12/98	1.74	PW08	11/12/98	0.01516	MW11	08/08/96	0.12099	MW48	2/18/98	0.001	MW41	2/17/98	0.002
PW08	12/31/98	1.51	PW08	12/31/98	0.01398	MW11	08/07/95	0.126	MW48	8/11/98	0.001	MW41	5/13/98	0.0012
PW08	1/29/99	1.33	PW08	1/29/99	0.02630	MW11	02/06/95	0.15999	MW48	11/19/97	0.002	MW41	8/11/98	0.00069
PW08	2/26/99	1.15	PW08	2/26/99	0.01564	MW11	08/15/94	0.15999				MW48	2/18/98	0.0004
PW08	3/31/99	1.43	PW08	3/31/99	0.01848	MW11	11/07/94	0.18				MW48	8/11/98	0.0004
PW08	4/31/99	1.33	PW08	4/31/99										

1,2-DCA was detected only once out of a total of 92 samples analyzed (1 percent detection frequency) at a concentration of 0.002 mg/L. Because this chemical was detected at a low frequency and concentration, it was not included in the Tier 2 risk calculations for this exposure setting.

The EPCs for iron and manganese were calculated by dividing the 95 percent UCL concentration (from Table 3-2) by the mixing factor of 47 derived in Section 3.4.5.2.2. The EPCs are calculated as follows:

$$EPC_{iron} = \frac{10.1\ mg/L}{47} = 0.22\ mg/L$$

$$EPC_{manganese} = \frac{0.992\ mg/L}{47} = 0.021\ mg/L$$

Because the estimated EPCs for iron and manganese are less than concentrations measured in regional background, these two metals were not included in the Tier 2 risk calculation for this setting.

For future onsite groundwater usage, the following assumptions are used to estimate potential RME for an occupational scenario:

- A 70-kg occupational worker is assumed to work full-time at the RMC-Troutdale facility, 250 days per year over 25 years of employment, consuming 1 liter of drinking water/day and showering for 15 minutes per day at the plant.

The results of noncancer and excess lifetime cancer risk estimates for future occupational workers are summarized in Table 3-9. These results indicate that the ELCR is less than the EPA target risk level of 1×10^{-4}, and that the HQs for chemicals detected in groundwater, as well as the total HI, are well below the EPA and DEQ target risk levels of 1.0. None of the constituents evaluated exceed respective MCLs. The primary contributor to ELCR is PCE (6×10^{-6}) through the inhalation route of exposure. The primary contributor to the noncancer HQ is fluoride (95 percent). The future onsite exposure assumptions and risk calculation data tables are provided in Appendix E, Tables E-9 through E-16.

Current Offsite Water Use. Current offsite water use was evaluated at the drinking water tap supplying well water at Sundial Marine Tug & Barge and Gresham Sand & Gravel, identified as the only currently active wells downgradient of RMC. Tap water fluoride concentrations were measured from both locations between September 1994 and February 1997 (a total of four sampling rounds at each location). The EPC for fluoride was calculated as the 95 percent UCL concentration from these two wells and is equal to 0.35 mg/L. A summary of fluoride concentrations for the Gresham Sand & Gravel and Sundial Marine Tug & Barge wells is presented in Table 3-15.

For current offsite groundwater usage, the following assumptions are used to estimate potential RME for an occupational scenario:

- A 70-kg occupational worker is assumed to work full-time at Sundial Marine Tug & Barge or Gresham Sand & Gravel, 250 days per year over 25 years of employment, consuming 1 liter of drinking water/day and showering for 15 minutes per day at his or her place of work.

Table 3-15
Summary of COPC Concentrations Detected at Sundial Marine Tug & Barge and Gresham Sand & Gravel

Sample ID	Date Collected	Fluoride [a]	
GS01-130-05597-0	2/24/97	0.125	U
GS01-04696-0	2/15/96	0.125	U
GS01-13295-0	5/12/95	0.37	
GS01-24994-0	9/6/94	0.25	U
SM01-03996-0	2/8/96	0.31	
SM01-13095-0	5/10/95	0.45	
SM01-24994-0	9/6/94	0.25	U
SM01-05797-0	2/26/97	0.125	U
Number of Samples		7	
Mean		0.27	
Standard Deviation		0.12	
t(n-1)		1.895	
95 Percent UCL		0.35	
Maximum Concentration		0.45	

[a] *Concentrations reported as not detected at or above the method* reporting limit (U qualifier) were converted to half the MRL for the purpose of calculating the 95 percent UCL concentration.

The risk estimates for current occupational workers are summarized in Table 3-9. These results indicate that the HQs for chemicals detected in groundwater, as well as the total HI, are well below the EPA and DEQ target risk levels of 1.0. The current offsite exposure assumptions and risk calculation data tables are provided in Appendix E, Tables E-17 through E-24.

Future Offsite Water Use. The eight COPCs carried forward from Tier 1 were evaluated to determine whether potential risks may be posed under future offsite water use conditions at a hypothetical occupational or residential well at Fairview Farms. As discussed in Section 3.4.3.2, exposure concentrations were estimated at a hypothetical well constructed at the location where the highest fluoride concentrations could potentially occur in offsite groundwater downgradient of the RMC facility and where the greatest exposure potential could occur within the Fairview Farms property. The long-term concentration of fluoride in the Fairview Farms hypothetical well was estimated to be 5.8 mg/L for the occupational exposure scenario and 7.1 mg/L for the residential exposure scenario. A description of the capture zone analysis for the occupational and residential exposure scenarios is presented in Appendix C.

For nonfluoride constituents identified during Tier 1 for evaluation during Tier 2, an evaluation was conducted to determine whether elevated site groundwater concentrations were located within the capture zone of the Fairview Farms hypothetical well. The model simulations described previously were used to evaluate whether the capture zone for the Fairview Farms hypothetical well includes any of these locations.

The capture zone analyses indicated that none of the onsite monitoring well locations with concentrations exceeding MCLs lie within the capture zone of the hypothetical well under either the occupational or the residential exposure scenario. Therefore, nonfluoride constituents were excluded from the risk calculations for the Fairview Farms hypothetical well.

For future offsite groundwater usage, the following assumptions are used to estimate potential RME for occupational and residential scenarios:

- A 70-kg occupational worker is assumed to work full-time at the RMC-Troutdale facility, 250 days per year over 25 years of employment, consuming 1 liter of drinking water/day and showering for 15 minutes per day at the plant.
- A 70-kg adult is assumed to reside in the Fairview Farms area, 350 days per year over 30 years, consuming 2 liters of drinking water/day, and showering for 15 minutes per day at home.

The risk estimates for future occupational workers and residents are summarized in Table 3-9. The future offsite exposure assumptions and risk calculation data tables are provided in Appendix E, Tables E-17 through E-24. The results indicate that the total HI for the residential scenario exceeds the EPA and DEQ target HI of 1.0 under both RME and average-case assumptions, but not for the occupational scenario. The residential RME HI is 3.2 (average case 1.8) and the occupational RME HI is 0.95.

3.7 Identification of Major Uncertainties and Assumptions

Several sources of uncertainty affect the overall estimates of human health and ecological risk at RMC-Troutdale presented in this baseline RA. The sources are generally associated with:

- Sampling, analysis, and data evaluation
- Chemical fate
- Exposure estimation
- Toxicological data

These sources of uncertainty are discussed in Section 5 of Part 1 of the baseline RA (CH2M HILL, 1999a). Additional sources of uncertainty specific to this Part 2 baseline RA include:

- **Influence of Early Actions.** One of the primary purposes of the early actions taken to date (for example, soil removals at east potliner) was to reduce potential contributions from migration of constituents from soil to groundwater. Because some of these early actions have been relatively recent, this baseline RA may incorporate groundwater concentrations that do not yet fully reflect the effect of these actions. As a result, the actual groundwater concentrations of constituents influenced by these completed early action events would likely be lower and actual risk would be proportionally lower.

- **Estimation of Future Onsite Groundwater Concentrations.** For evaluation of the onsite future water use setting, exposure point concentrations in groundwater were interpolated from measured concentrations in the most contaminated adjacent shallow water-bearing zones. The interpolation approach assumes that constituents will move in groundwater at a rate similar to fluoride. Because fluoride is known to migrate in groundwater more readily than other site COPCs, tap water EPC estimates are considered conservative and could substantially overestimate actual future concentrations.
- **Estimation of Future Offsite Groundwater Concentrations.** Future offsite groundwater concentrations were estimated using a site-scale groundwater flow model. This procedure assumes that there is a future well located in the northeast corner of Fairview Farms, where the highest concentrations of fluoride in offsite groundwater are present downgradient of the RMC facility. The hypothetical well design and pumping characteristics were based on reasonable expectations for a future well. If a future well is placed at this location, and well characteristics are different from those assumed here, the risk estimates presented here may overestimate or underestimate actual risks. The assumptions associated with the estimation of future offsite concentrations in groundwater are discussed in Appendix C.

SECTION 4

Ecological Risk Assessment

SECTION 4

Ecological Risk Assessment

As outlined in the conceptual exposure model for ecological receptors at RMC-Troutdale, the only feasible pathway by which site-related constituents in groundwater could reach ecological receptors is by discharge to the Columbia and Sandy Rivers. This section summarizes the evaluation of this pathway, which was presented in the *Draft Surface Water and Sediment Areas Addendum to the RI/FS Work Plan* (CH2M HILL, 1998a). This Part 2 RA addresses only groundwater. The potential ecological risks posed by constituents directly measured in surface water and sediment collected during the RI are evaluated in Part 1 of this RA (CH2M HILL, 1999a).

4.1 Calculation of In-stream Mixing in Rivers

On the basis of the May 22, 1997, meeting with EPA and other resource trustees (DEQ, USFWS), the ecological assessment endpoint selected for the rivers is survival and health of fingerling stages of anadromous and resident fish. To assess the potential exposure concentrations in the rivers, calculations were conducted to estimate the amount of mixing that occurs in each river and the resulting fluoride concentrations. The objective of the calculations was to conservatively estimate the feasible in-stream concentrations in the two rivers so that ecological risk could be evaluated.

The magnitude of mixing between groundwater and surface water was calculated as a mixing factor that is a ratio of the sum of groundwater and surface water flows divided by the groundwater flow. This mixing factor was then used with the groundwater constituent concentrations to estimate in-stream concentrations after mixing.

Fluoride measured at the temporary Geoprobe® locations along the rivers was used to estimate the potential in-stream exposure concentration of fluoride. The calculations are based on the average vertical fluoride concentrations in groundwater, measured in the upper 60 feet of the Geoprobes along each river (7 Geoprobes along the Columbia River and 10 Geoprobes along the Sandy River). The upper 60 feet represent the interval where fluoride was detected in groundwater. The average was calculated, using one-half the detection limit of 0.25 mg/L for the nondetect values. For nonfluoride constituents, maximum concentrations measured in shallow or intermediate wells north of the COE dike were evaluated to determine whether levels are high enough to pose in-stream risks.

In-stream concentrations were estimated assuming a range of river flow conditions and a range of assumed stream sections available for mixing. This set of conditions provided a range of plausible conditions of aquatic exposures. To provide a range of river flow conditions, these calculations were performed for three separate river flow rates:

- The 7Q10 flow (7-day sustained low flow expected to occur once every 10 years)
- The minimum monthly low flow
- The mean annual flow

In addition, these calculations were performed for three separate assumed percentages of total river flow available for mixing. The selected percentages for each river were based on the minimum estimated cross-sectional river bed area for groundwater discharge, the maximum estimated area for groundwater discharge, and an intermediate area.

The calculation results should be considered conservative because they are based on:

- The seasonally highest observed hydraulic gradients in the upper gray sand
- The highest upper gray sand hydraulic conductivity values measured north of the COE dike
- River flow gauges far upstream of the Troutdale site, where the flows are smaller because they do not include tributary flows between the gauges and the site

The calculations and assumptions used to develop the mixing factors and to calculate the in-stream fluoride concentrations are provided in detail in the *Draft Surface Water and Sediment Areas Addendum to the RI/FS Work Plan* (CH2M HILL, 1998a). In addition to fluoride, these mixing factors are used to estimate in-stream concentrations of nonfluoride constituents by dividing the groundwater concentrations by the mixing factor.

The mixing calculations for the Columbia River indicate that, even under the most conservative river flow conditions (7Q10), the mixing factor ranges between about 34,000 and 84,000 (CH2M HILL, 1998a). The mixing calculations for the Sandy River indicate that, under the most conservative flow conditions (7Q10), the mixing factor ranges from about 90 to 450. The mixing factors increase for higher river flow rates and higher percentages of the river flow that are available for mixing.

4.2 Ecological Risk Estimates for Groundwater Discharging to the Columbia River

Fluoride is the most prevalent site-related constituent detected in site groundwater, but there are no ambient water quality criteria (AWQC) available. Therefore, available freshwater aquatic toxicity data were compiled from literature sources and are summarized in Table 4-1. When multiple acute or chronic toxicity studies were available for a given aquatic species, the average toxicity is reported for that individual species. Individual toxicity studies are summarized in Appendix H of *Draft Baseline Risk Assessment, Part 1—Nongroundwater Media* (CH2M HILL, 1999a). These results provide an indication of fluoride toxicity potential to the aquatic community as a whole.

Potential exposure to aquatic organisms was evaluated on the basis of a comparison of calculated surface water concentrations of constituents with freshwater toxicity benchmarks. For fluoride, calculated surface water concentrations (based on 7Q10 flow, minimum monthly flow, and mean annual flow) are provided in Table 4-2. On the basis of the toxicity values shown in Table 4-1 and the calculated in-stream fluoride concentrations in Table 4-2, no adverse effect is expected to aquatic organisms under any of the most plausible streamflow conditions. For the purpose of this evaluation, toxicity studies based on exposure durations of greater than 4 days were considered chronic and studies based on exposure durations of equal to or less than 4 days were considered acute. These definitions are consistent with conventional use by regulatory agencies [that is, for the National Pollutant Discharge Elimination System (NPDES)].

Table 4-1
Species-Specific Averages for Aquatic Toxicity of Fluoride Compounds[a]

Species	Acute Toxicity Average LC_{50} (mg/L)	Chronic Toxicity (mg/L)
Brown trout	111.3	2
Caddisfly	29.6	25.1
Coho salmon	--	10
Daphnia magna	245.7	3.7
Fathead minnow	254.5	--
Freshwater crab	--	13
Mosquitofish	418	--
Rainbow trout	142.5	27.6
Snake-head catfish	--	4.5
Three-spine stickleback	393.3	--

[a]Value represents species average when multiple studies were available.

Table 4-2
Estimated Incremental Increase in Fluoride Concentration in the Columbia River, Based on Measured Groundwater Concentrations Adjacent to the River

River Flow Condition	Fluoride Concentration (mg/L) Based on Portion of River Flow Available for Mixing		
	20 Percent	40 Percent	50 Percent
7Q10	0.00005	0.00003	0.00002
Minimum Monthly	0.00004	0.00002	0.00002
Mean Annual	0.00002	0.00001	0.00001

A comparison of estimated exposure concentrations with freshwater toxicity benchmarks for nonfluoride constituents is provided in Table 4-3. Calculated surface water concentrations after mixing are well below freshwater toxicity benchmarks, and calculated fluoride concentrations are well below levels that would be expected to produce an adverse effect to aquatic organisms.

Table 4-3
Comparison of Calculated Surface Water Concentrations in the Columbia River with Freshwater Toxicity Benchmarks

	Maximum Detected Values in Shallow and Intermediate Groundwater North of the COE Dike[a]		Calculated In-stream Concentration	Freshwater Screening Criteria	
Analyte	**Sample Location of Max. Detected Value**	**Maximum Detected Value (µg/L)**	**Maximum Concentration (µg/L)[b]**	**Acute Toxicity (µg/L)**	**Chronic Toxicity (µg/L)**
1,1,1-Trichloroethane	MW30-030	2.0	0.00003	18000 [c(1),d]	1800 [c(1),f]
Aluminum	MW21-012	13,700	0.204	750 [c(6),g]	87 [c(6),g]
Acenaphthene	MW21-012	0.2	0.000003	1700 [c(1),d]	520 [c(1),d]
Antimony (III)	MW21-012	1.1	0.00002	88 [c(7)]	30 [c(7)]
Barium	MW30-100	150	0.002		5800 [h]
Beryllium	MW21-012	24.4	0.0004	130 [c(1),d]	5.3 [c(1),d]
Cadmium	MW22-027	2.2	0.00003	2.2 [c(2),e]	0.8 [c(2),e]
Calcium	MW30-100	68,100	1.016		116000 [h]
Chloride	MW21-063	87,800	1.310	860000 [c(5)]	230000 [c(5)]
Chromium (VI)	MW08-027	24	0.0004	16 [c(2)]	11 [c(2)]
Copper	MW21-012	126.0	0.002	11 [c(2),e]	8 [c(2),e]
Cyanide, Amenable	MW08-027	160	0.002	22 [c(2)]	5.2 [c(2)]
Fluorene	MW21-012	0.133	0.000002		520 [i]
Iron	MW21-012	121,000	1.806		1000
Lead	MW08-027	17.5	0.0003	43 [c(2),e]	1.7 [c(2),e]
Magnesium	MW30-100	35,900	0.536		82000 [h]
Manganese	MW30-100	3,480	0.052		1100 [h]
Mercury	MW21-012	0.21	0.000003	2.4 [c(2)]	0.012 [c(2)]
Naphthalene	MW21-012	2.0	0.00003	2300 [c(1),d]	620 [c(1),d]
Nickel	MW21-063	50	0.001	921 [c(3),d]	102 [c(3),d]
Nitrate-N	MW30-030	5,900	0.088		
P-Isopropyltoluene	MW21-012	4.0	0.0001		1750 [j]
Potassium	MW30-100	5,900	0.088		53000 [h]
Silver	MW27-81	3.8	0.00006	0.92 [c(7)]	0.12 [c(7)]
Sodium	MW21-012	200,000	2.985		680000 [h]
Sulfate	MW21-063	86,700	1.294		
Toluene	MW08-127	8.0	0.0001	17500 [c(1),d]	1750 [c(1),f]
Vanadium	MW21-025	5.0	0.0001		80 [h]
Zinc	MW27-045	5.1	0.0001	76 [c(4),e]	69 [c(4),e]

[a] Monitoring wells used for this comparison: MW08-027, MW08-127, MW09-030, MW20-026, MW21-012, MW21-025, MW21-063, MW22-027, MW23-025, MW27-045, MW27-081, MW30-030, MW30-100, MW51-069, MW52-045.

[b] Assumes conservative scenario: 7Q10 river flow, mixing with 40 percent of river (mixing factor = 67,000)

[c] Ambient Water Quality Criteria for Protection of Freshwater Aquatic Life. The acute criterion reflects a 1-hour average concentration not to be exceeded more than once every 3 years on average. The chronic criterion reflects a 4-day average not to be exceeded more than once in 3 years on average.
Sources:
(1) From 45 *Federal Register* 79318, November 28, 1980.
(2) From 50 *Federal Register* 30784, July 29, 1985.
(3) From 51 *Federal Register* 43665, December 3, 1986.
(4) From 52 *Federal Register* 6213, March 2, 1987.
(5) From 53 *Federal Register* 19028, May 26, 1988.
(6) From 53 *Federal Register* 33177, August 30, 1988.
(7) From 55 *Federal Register* 19986, May 14, 1990.

[d] Not enough data were available to derive numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effects levels. From 45 *Federal Register* 79318. November 24, 1980.

[e] Criterion is dependent on the hardness of the water.
Assumed hardness (mg/L): 60.

[f] Acute criteria = chronic criteria / 10.

[g] Criteria are pH and temperature dependent.

[h] Criteria from G.W. Suter, 1996.

[i] Criterion based on acenaphthene criterion.

[j] Criterion based on toluene criterion.

4.3 Ecological Risk Estimates for Groundwater Discharging to the Sandy River

Using the same methods described for the Columbia River, potential exposure to aquatic organisms was evaluated on the basis of a comparison of calculated surface water fluoride concentrations with freshwater toxicity benchmarks. On the basis of the fluoride toxicity concentrations in Table 4-1 and the calculated fluoride concentrations in Table 4-4, no adverse effect is expected to aquatic organisms under any of the most plausible streamflow conditions.

Table 4-4
Estimated Incremental Increase in Fluoride Concentration in the Sandy River, Based on Measured Groundwater Concentrations Adjacent to the River

River Flow Condition	Fluoride Concentration (mg/L) Based on Percent of River Flow Available for Mixing		
	10 Percent	25 Percent	50 Percent
7Q10	0.006	0.002	0.001
Minimum Monthly	0.003	0.001	0.0005
Mean Annual	0.0006	0.0002	0.0001

A comparison of estimated exposure concentration with freshwater toxicity benchmarks for nonfluoride constituents is provided in Table 4-5. Calculated surface water concentrations are well below levels that would be expected to produce an adverse effect to aquatic organisms, indicating that groundwater discharge to the Sandy River is not expected to pose an unacceptable risk to aquatic organisms.

The results of the in-stream mixing and risk evaluations presented here are consistent with the evaluation (in Part 1 of this RA) of the ecological risks posed by constituents directly measured in surface water and sediment collected during the RI.

Table 4-5
Comparison of Calculated Surface Water Concentrations in the Sandy River with Freshwater Toxicity Benchmarks

	Maximum Detected Values in Shallow and Intermediate Groundwater Upgradient of the Sandy River[a]		Calculated In-stream Concentration	Freshwater Benchmarks			
Analyte	Sample Location of Max. Detected Value	Maximum Detected Value (μg/L)	Maximum Concentration (μg/L)[b]	Acute Toxicity (μg/L)		Chronic Toxicity (μg/L)	
Aluminum	MW10-023	730	3.3	750	c(5),f	87	c(5),f
Barium	MW10-023	60	0.27			5800	g
Beryllium	MW10-023	0.62	0.003	130	c(1),d	5.3	c(1),d
Calcium	MW10-023	27,700	126			116000	g
Chloride	MW10-023	6,940	32	860000	c(4)	230000	c(4)
Chromium (VI)	MW10-023	20	0.091	16	c(2)	11	c(2)
Copper	MW10-023	2.4	0.011	11	c(2),e	8	c(2),e
Iron	MW10-023	32,600	148			1000	
Lead	MW10-023	4.1	0.019	43	c(2),e	1.7	c(2),e
Magnesium	MW10-023	22,600	103			82000	g
Manganese	MW10-023	1,620	7.4			1100	g
Nickel	MW10-023	12.7	0.06	921	c(3),d	102	c(3),d
Nitrate-N	MW10-090	890	4.0				
Potassium	MW10-023	3,750	17			53000	g
Silver	MW53-034	3.0	0.014	0.92	c(6)	0.12	c(6)
Sodium	MW10-023	16,000	73			680000	g
Sulfate	MW10-023	111,000	505				

[a] Monitoring wells used for this comparison: MW53-034, MW10-023, MW10-090.

[b] Assumes most conservative scenario: 7Q10 river flow, assuming groundwater mixing with 25 percent of river flow (mixing factor = 220).

[c] Ambient Water Quality Criteria for Protection of Freshwater Aquatic Life. The acute criterion reflects a 1-hour average concentration not to be exceeded more than once every 3 years on average. The chronic criterion reflects a 4-day average not to be exceeded more than once every 3 years on average.
Sources:
(1) From 45 *Federal Register* 79318, November 28, 1980.
(2) From 50 *Federal Register* 30784, July 29, 1985.
(3) From 51 *Federal Register* 43665, December 3, 1986.
(4) From 53 *Federal Register* 19028, May 26, 1988.
(5) From 53 *Federal Register* 33177, August 30, 1988.
(6) From 55 *Federal Register* 19986, May 14, 1990.

[d] Not enough data were available to derive numerical national water quality criteria for aquatic life protection for these chemicals. Values reflect lowest reported effects levels. From 45 *Federal Register* 79318. November 24, 1980.

[e] Criterion is dependent on the hardness of the water.
Assumed hardness (mg/L): 60.

[f] Criteria are pH and temperature dependent.

[g] Criteria from G.W. Suter, 1996.

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References

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APPENDIX A

Conceptual Exposure Models

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Figures

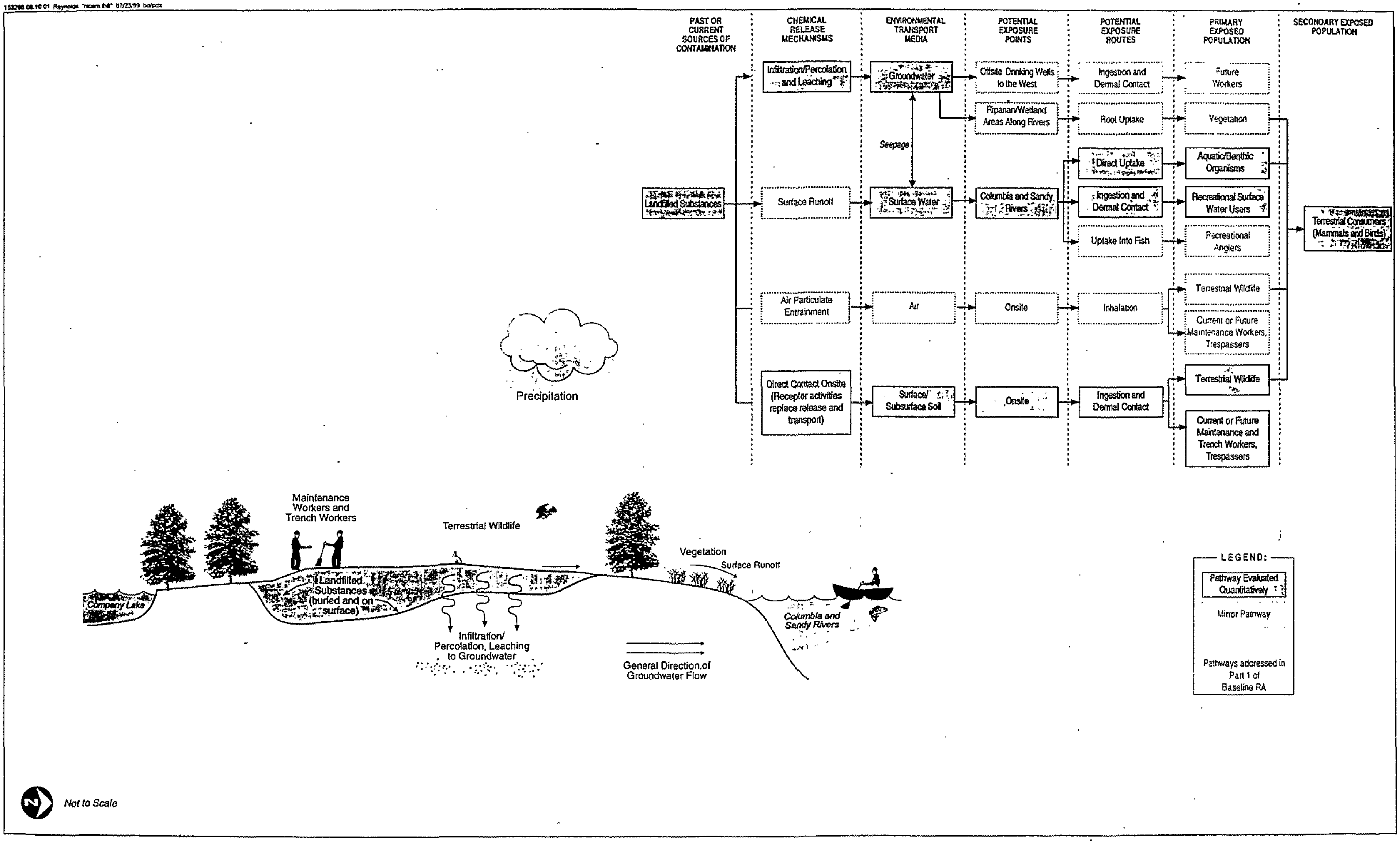

Figure A-1

North Landfill Conceptual Exposure Model

REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment, Part 2-Groundwater

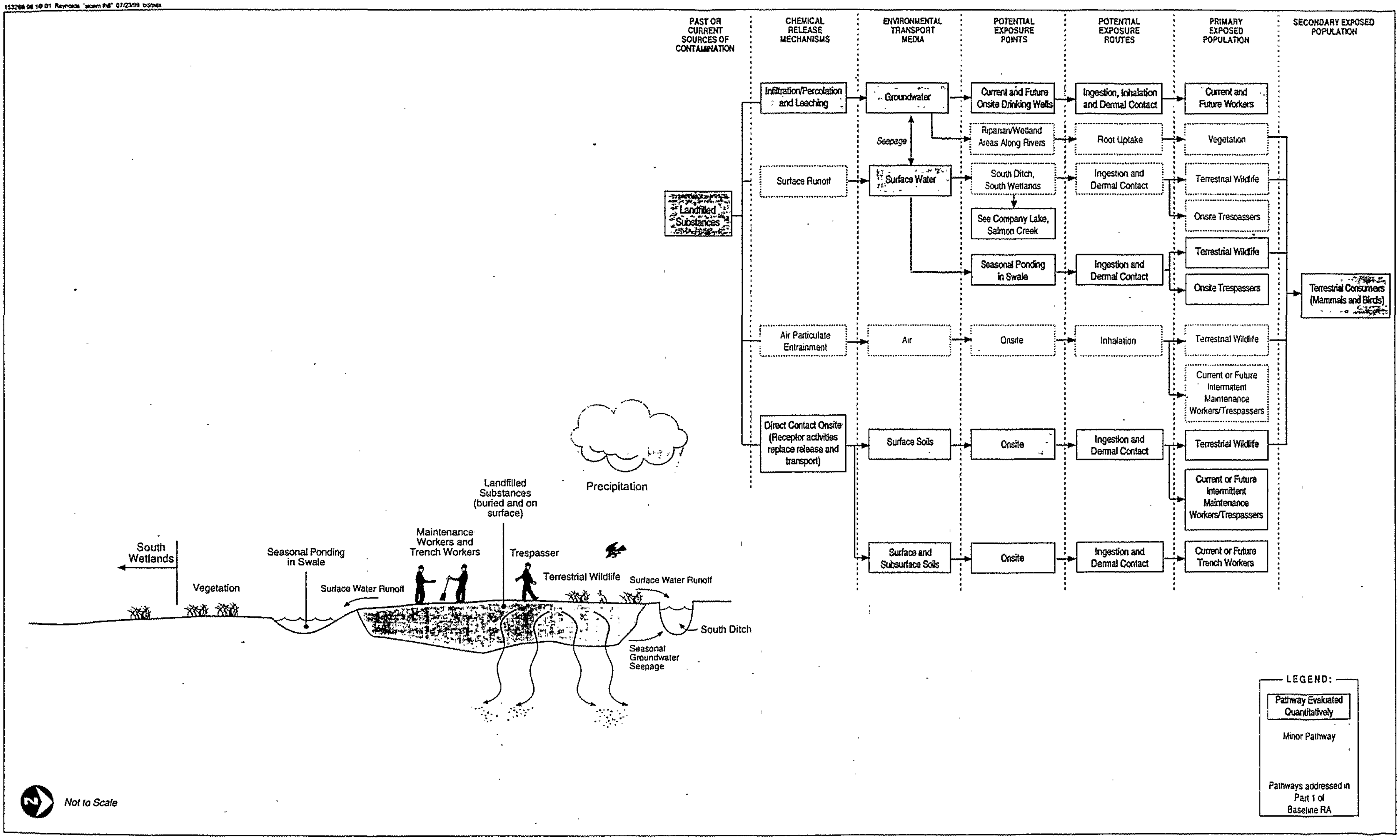

Figure A-2

South Landfill Conceptual Exposure Model

REYNOLDS METALS COMPANY

TROUTDALE, OREGON

Baseline Risk Assessment, Part 2-Groundwater

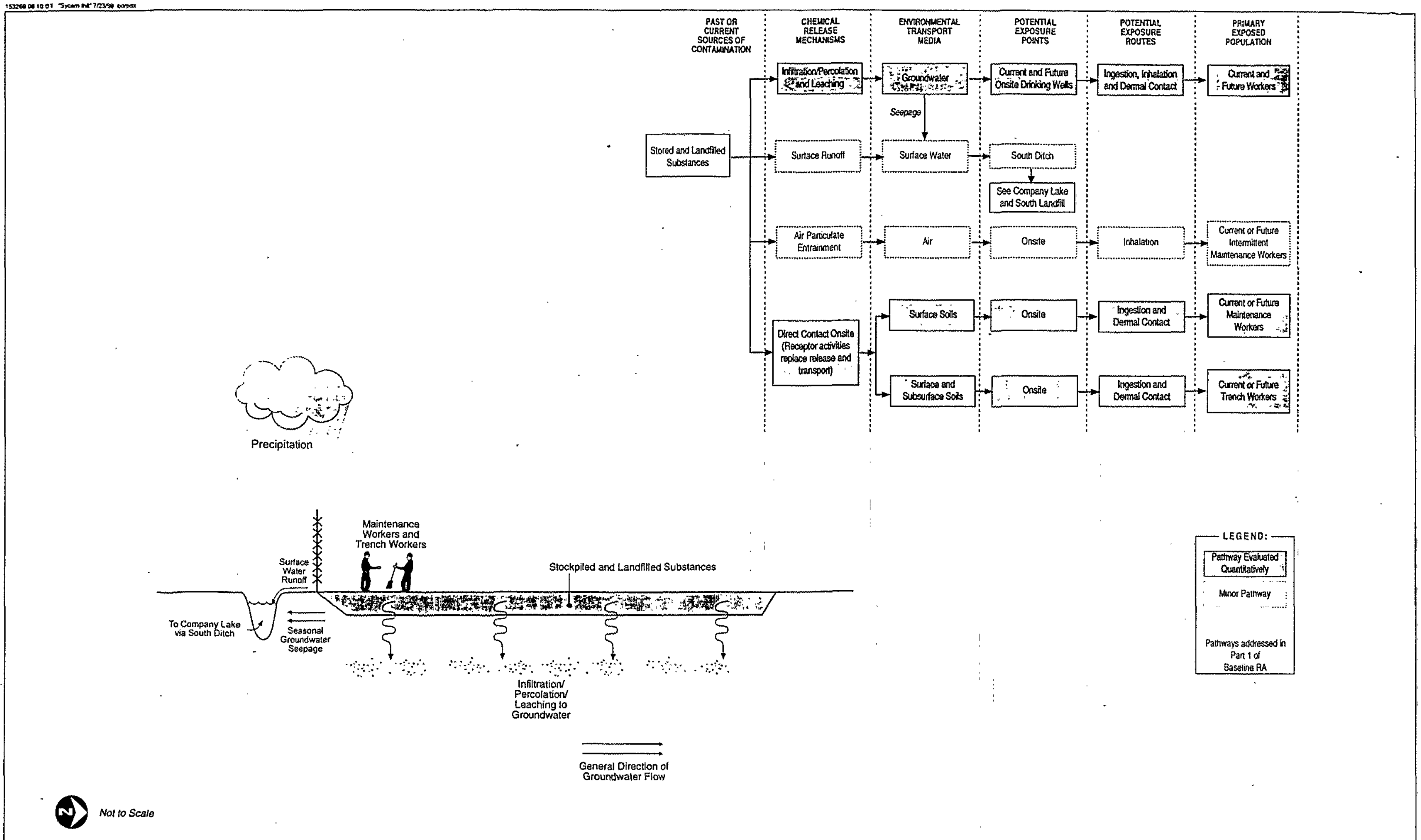

Figure A-3
Scrap Yard Conceptual Exposure Model
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment, Part 2-Groundwater

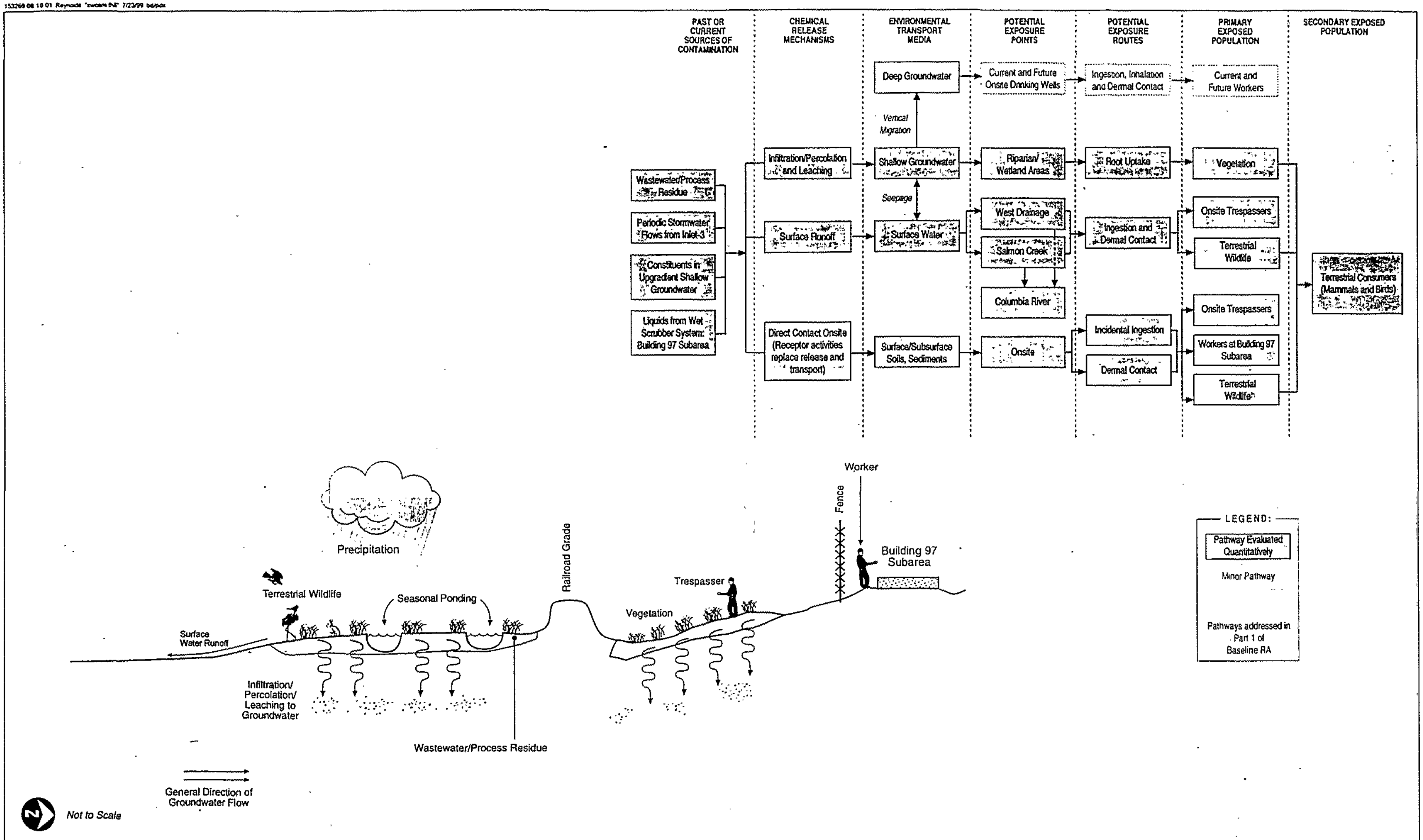

Figure A-4

South Wetlands Conceptual Exposure Model

REYNOLDS METALS COMPANY

TROUTDALE, OREGON

Baseline Risk Assessment, Part 2-Groundwater

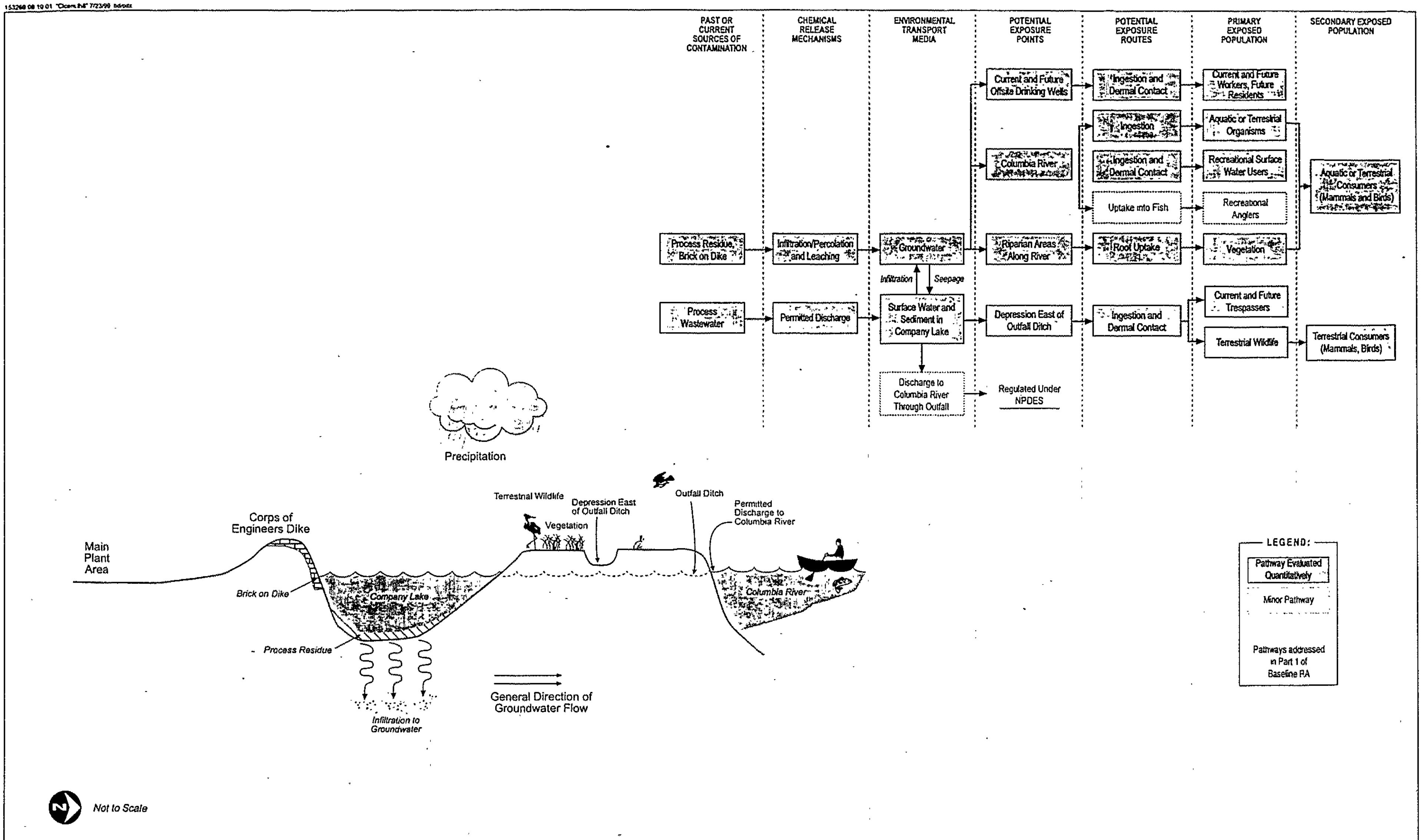

Figure A-5

Company Lake Conceptual Exposure Model

REYNOLDS METALS COMPANY

TROUTDALE, OREGON

Baseline Risk Assessment, Part 2-Groundwater

APPENDIX B

Evaluation of Background Concentrations

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APPENDIX B

Evaluation of Background Concentrations

Background groundwater concentrations of naturally occurring inorganic chemicals were established using samples taken from locations considered upgradient of or adjacent to the Troutdale site and that have not been affected by site activities. Available background monitoring wells include MW03 (screened at shallow, intermediate, and deep zones) and MW05 (screened at shallow zone) installed at the site during the RI, six City of Troutdale wells (all screened in the deep zone), and seven Portland Water Bureau wells (all screened in the deep zone in the sand gravel aquifer system). Summaries of inorganic chemical concentrations detected in these background wells are provided in Tables B-1, B-2, and B-3. These data provide the basis for determining whether onsite groundwater constituents are site-related or attributable to natural background.

Evaluation of Arsenic, Iron, and Manganese. Three of the eight COPCs identified to be carried forward to the Tier 2 RA were metals: arsenic, iron, and manganese. An evaluation was conducted to identify the likelihood that arsenic, iron, and manganese occurring in groundwater have resulted from historical site releases. The hypothesis for this evaluation was that if these metals originated from site releases, they would likely co-occur with fluoride in groundwater. Upon regression analysis, a strong spatial association between elevated fluoride concentrations and elevated concentrations of these metals (as indicated by a high correlation coefficient or R^2) would suggest they result from co-releases at RMC. If the highest concentrations of arsenic, iron, or manganese do not co-occur with high fluoride levels, it is anticipated that these metal concentrations represent natural variation. The results of these comparisons are presented in scatter plots plotting fluoride concentrations against arsenic, iron, and manganese concentrations measured in synoptic samples.

A scatter plot of arsenic versus fluoride concentrations detected in groundwater is presented in Figure B-1. Scatter plot results appear to show two distinct sample populations clustered into two data groups. The first sample population represents low arsenic concentrations (less than 0.2 mg/L) that are correlated with low fluoride concentrations (less than 200 mg/L); it is likely that these arsenic concentrations are at naturally occurring levels. The second sample population represents high arsenic concentrations (exceeding the MCL, between 0.08 and 0.18 mg/L) that are correlated with higher fluoride concentrations (greater than 400 mg/L); it is likely that these arsenic concentrations can be attributed to site releases. All arsenic concentrations in the second sample population were measured at station MW11-017 between November 1994 and August 1998. Arsenic concentrations of less than 0.02 mg/L represent all remaining locations included in this evaluation. The R^2 value for this scatter plot is 0.8455, which indicates a significant correlation between arsenic and fluoride concentrations. Because there is significant correlation between fluoride and arsenic concentrations at station MW11-017, arsenic was carried forward to Tier 2. However, all remaining arsenic concentrations are likely to be at naturally occurring levels in groundwater.

Table B-1
Summary of Metals Concentrations from Monitoring Wells
Located Upgradient of the RMC-Troutdale Site
Sample Location: Portland Water Bureau Wells

Well ID	33AD-569	PWB1-USG	BLA-4	PWB-41	PWB-4D	PWB-51	PWB-5D
Aquifer	SGA	SGA	SGA	SGA	SGA	SGA	SGA
Date Collected	6/17/97	5/20/97	7/29/97	7/30/97	7/30/97	7/29/97	7/29/97
Metals							
Arsenic	<0.001	<0.05	0.002	0.001	0.001	0.002	0.002
Barium	0.057	0.008	0.051	0.028	0.059	0.098	0.069
Calcium	15	13	23	14	13	41	33
Cadmium	<0.001	<0.005	<0.001	0.010	0.001	0.005	0.008
Copper	<0.01	<0.02	<0.01	0.045	0.012	0.070	0.035
Iron	0.17	<0.05	0.22	0.70	0.82	1.00	3.20
Lead	<0.001	<0.05	<0.001	0.004	0.001	0.004	0.004
Magnesium	6.1	4.8	12.0	4.8	9.5	8.3	8.6
Mercury	<0.001	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum	0.078	0.027	0.130	0.028	0.033	0.019	0.110
Potassium	3.3	3.0	3.7	1.9	12.0	12.0	4.3
Selenium	<0.001	<0.1	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	<0.001	<0.02	<0.010	0.067	0.034	0.1	0.17
General Chemical Parameters							
Ammonia	0.088	<0.2	<0.02	0.066	0.066	0.110	0.023
Nitrate	<0.01	<0.01	<0.01	1.00	1.00	0.05	0.01
Alkalinity	95	79	120	65	118	168	105
Chloride	1.5	1.3	1.2	1.5	3.0	1.4	1.4
Fluoride	0.12	<0.2	0.17	0.1	0.11	0.09	0.13
Sulfate	1.2	1.9	2.2	2.6	8.8	5.1	1.7

Notes:
Concentrations are mg/L.
All wells are screened at the deep zone (>200 ft).

Table B-2
Summary of Metals Concentrations from Monitoring Wells Located Upgradient of the RMC-Troutdale Site
Sample Location: RMC-Troutdale Site

Well ID	MW03-017													
Date Collected	07/94	11/94	02/95	05/95	08/95	08/96	11/96	02/97	05/97	08/97	11/97	02/98	08/98	02/99
Parameter														
Aluminum	2.0					0.19	0.06	0.08	0.06	0.06	0.05 U	0.05 U	0.05 U	
Arsenic	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.001 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	
Barium	0.03					0.02 U	0.02	0.02 U	0.02 U	0.02 U	0.02 U			
Beryllium	0.02 U	0.02 U	0.02 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	0.0003 U	
Cadmium	0.0003 U	0.0200 U	0.0003 U	0.0040 U	0.0040 U	0.0020 U	0.0012 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U			
Chromium	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.01 U	0.00 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	
Cyanide, Total	0.02 U	0.02 U	0.02 U	0.005 U	0.005 U	0.002 U	0.001 U	0.002 U	0.002 U	0.002 U	0.002 U			
Copper	0.01 U	0.01 U	0.01 U	0.02 U	0.02 U	0.07	0.01 U	0.01 UJ	0.02 U	0.02 U	0.02 U			
Fluoride	0.50 U	0.50 U	0.50 U	0.57	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.40 U	0.40 U	0.40 U	0.40 U	0.40 U
Iron	5.0		4.9			4.5	5.8	4.5	5.2	4.8	5.9			
Lead	0.004 U	0.004 U	0.004 U	0.005 U	0.005 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	
Manganese	0.26							0.09						
Vanadium	0.02 U						0.003	0.02 U	0.02 U	0.02 U	0.02 U			
Zinc	0.05 U	0.10 U	0.05 U	0.05 U	0.05 U	0.05 U	0.003	0.05 U	0.05 U	0.05 U	0.05 U			

Well ID	MW03-098									MW03-175					
Date Collected	08/96	11/96	02/97	05/97	08/97	11/97	02/98	08/98	02/99	08/96	11/96	02/97	05/97	08/97	11/97
Parameter															
Aluminum	0.06	0.05	1.18	0.05 U	0.05 U	0.15	0.05 U	0.05 U		0.05 U	0.01 U	0.05 U	0.05 U	0.05 U	0.05 U
Arsenic	0.006	0.006	0.007	0.007	0.006	0.007	0.007	0.007		0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U
Barium	0.02 U	0.02	0.03	0.02 U	0.02 U	0.02 U				0.02 U	0.01	0.02 U	0.02 U	0.02 U	0.02 U
Beryllium	0.0003 U	0.0003 U	0.0004	0.0003 U	0.0004	0.0003 U	0.0003 U	0.0003 U		0.0003 U	0.0003 U	0.0004	0.0003 U	0.0003 U	0.0003 U
Cadmium	0.0020 U	0.0012 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U				0.0020 U	0.0029	0.0020 U	0.0020 U	0.0020 U	0.0020 U
Chromium	0.01 U	0.00 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U		0.01 U	0.00 U	0.01 U	0.01 U	0.01 U	0.01 U
Cyanide, Total	0.002 U	0.001 U	0.002	0.002 U	0.002 U	0.002 U				0.002 U	0.001 U	0.002 U	0.002 U	0.002 U	0.002 U
Copper	0.02 U	0.01 U	0.01 UJ	0.02 U	0.02 U	0.02 U				0.02 U	0.01 U	0.01 UJ	0.02 U	0.02 U	0.02 U
Fluoride	0.40	0.25 U	0.40	0.35	0.54	0.46	0.48	0.57	0.49	0.25 U	0.25 U	0.25 U	0.25 U	0.40 U	0.40 U
Iron	4.9	5.5	7.1	5.3	5.6	6.0				0.6	0.6	0.8	0.7	0.8	0.7
Lead	0.001 U	0.001 U	0.003	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U		0.001 U	0.055	0.001 U	0.001 U	0.001 U	0.001 U
Manganese	0.59		0.66							0.33		0.32			
Vanadium	0.02 U	0.002	0.02 U	0.02 U	0.02 U	0.02 U				0.02 U	0.001 U	0.02 U	0.02 U	0.02 U	0.02 U
Zinc	0.05 U	0.002	0.05 U	0.05 U	0.05 U	0.05 U				0.05 U	0.01	0.05 U	0.05 U	0.05 U	0.05 U

Table B-2
Summary of Metals Concentrations from Monitoring Wells Located Upgradient of the RMC-Troutdale Site
Sample Location: RMC-Troutdale Site

Well ID	**MW05-025**								
Date Collected	**07/94**	**08/96**	**11/96**	**02/97**	**05/97**	**08/97**	**11/97**	**02/98**	**08/98**
Parameter									
Aluminum	0.34	0.23	1.20	0.22	0.25	0.23	0.14	0.53	0.56
Arsenic	0.004 U	0.004 U	0.001 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U
Barium	0.03	0.02 U	0.03	0.02 U	0.02 U	0.02 U	0.02 U		
Beryllium	0.0200 U	0.0003 U	0.0003 U	0.0006	0.0003 U	0.0004	0.0003 U	0.0003 U	0.0003 U
Cadmium	0.0003 U	0.0020 U	0.0012 U	0.0020 U	0.0020 U	0.0020 U	0.0020 U		
Chromium	0.02 U	0.01 U	0.00	0.01 U	0.01	0.01 U	0.01 U	0.01 U	0.01 U
Cyanide, Total	0.020 U	0.002 U	0.003	0.002 U	0.004 U	0.002	0.002 U		
Copper	0.01 U	0.02 U	0.06	0.01 U	0.02 U	0.02 U	0.02 U		
Fluoride	0.50	0.25 U	0.25 U	0.25 U	0.25 U	0.40 U	0.40 U	0.40 U	0.40 U
Iron	0.4	0.3	1.8	0.2	0.4	0.3	0.2		
Lead	0.004 U	0.001 U	0.001 U	0.001 U	0.001 U	0.002	0.001 U	0.001 U	0.001 U
Manganese	0.02			0.02 U					
Vanadium	0.02 U		0.01	0.02 U	0.02 U	0.02 U	0.02 U		
Zinc	0.05 U	0.05 U	0.01	0.05 U	0.05 U	0.05 U	0.05 U		

Notes:
Shallow wells = MW03-017 and MW05-025.
Intermediate well = MW03-098.
Deep well = MW03-175.
U = indicates chemical was not detected.
J = indicates chemical concentration is an estimation.

Table B-3
Summary of Metals Concentrations from Monitoring Wells
Located Upgradient of the RMC-Troutdale Site
Sample Location: City of Troutdale Wells

Well ID	**Well #2**					**Well #3**					**Well #4**				
Well Screen Depth	**430-443 ft**					**510-586 ft**					**493-564 ft**				
Date Sampled	**4/5/93**	**5/13/93**	**7/14/93**	**10/25/93**	**3/12/96**	**4/5/93**	**5/13/93**	**7/14/93**	**10/25/93**	**3/12/96**	**4/5/93**	**5/13/93**	**7/14/93**	**10/25/93**	**3/12/96**
Aluminum					0.10 U					0.10 U					0.10 U
Antimony	0.005 U	0.005 U	0.01 U	0.005 U	5E-04 U	0.005 U	0.005 U	0.005 U	0.005 U	5E-04 U	0.005 U	0.005 U	0.005 U	0.005 U	0.0005 U
Arsenic	0.005 U		0.01 U	0.005 U	5E-04 U	0.005 U		0.005 U	0.005 U	0.001	0.005 U		0.005 U	0.005 U	0.0013
Barium	0.005 U		0 U	0.002 U	0.002 U	0.022		0.022	0.022	0.023	0.061		0.065	0.002 U	0.07
Beryllium	0.001 U	5E-04 U	0 U	0.0005 U	5E-04 U	0.001 U	0.0005 U	0.0005 U	5E-04 U	5E-04 U	0.001 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U
Cadmium	0.001 U		0 U	0.001 U	5E-04 U	0.001 U		0.001 U	0.001 U	5E-04 U	0.001 U		0.001 U	0.001 U	0.0005 U
Calcium					18					16					44
Chromium	0.003		0 U	0.001 U	0.001 U	0.003		0.001 U	0.001 U	0.001 U	0.008		0.001 U	0.001 U	0.001 U
Copper					0.02 U					0.02 U					0.02 U
Iron					0.05 U					0.05 U					0.05 U
Lead					5E-04 U					5E-04 U					0.0005 U
Magnesium					6.2					6.8					5.2
Manganese					0.026					0.073					0.075
Mercury	0.0005 U		0 U	0.005 U	5E-04 U	0.0005 U		0.0005 U	5E-04 U	5E-04 U	0.0005 U		0.0005 U	0.0005 U	0.0005 U
Nickel	0.05 U	0.01 U	0.01 U	0.01 U	0.01 U	0.05 U	0.01 U	0.01 U	0.01 U	0.01 U	0.05 U	0.01 U	0.01 U	0.01 U	0.01 U
Selenium	0.005 U		0.01 U	0.005 U	5E-04 U	0.005 U		0.005 U	0.005 U	6E-04	0.005 U		0.005 U	0.005 U	0.0026
Silver					5E-04 U					5E-04 U					0.0005 U
Sodium	19		20	20	20	19		21	21	20	110		120	120	120
Thallium	0.002 U	0.002 U	0 U	0.002 U	5E-04 U	0.002 U	0.002 U	0.002 U	0.002 U	5E-04 U	0.002 U	0.002 U	0.002 U	0.002 U	0.0005 U
Zinc					0.02 U					0.02 U					0.02 U
General Chemical Parameters															
Cyanide, Total	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U
Fluoride	0.2 U		0.2 U	0.2 U	0.2 U	0.2 U		0.2 U	0.2 U	0.2 U	0.3		0.3	0.3	0.3

Table B-3
Summary of Metals Concentrations From Monitoring Wells Located Upgradient of the RMC-Troutdale Site
Sample Location: City of Troutdale Wells

Well ID	Well 6					Well 7				Well 8
Well Screen Depth	422-532 ft					358-384, 464-525 ft				435-533 ft
Date Sampled	4/5/93	5/13/93	7/14/93	10/25/93	3/12/96	7/26/93	10/25/93	2/15/94	4/20/94	5/6/96
Aluminum					0.10 U					
Antimony	0.005 U	0.005 U	0.01 U	0.005 U	5E-04 U	0.005 U	0.005 U	0.005 U	0.005 U	5E-04
Arsenic	0.005 U		0.01	0.005 U	6E-04	0.005 U	0.005 U	0.005 U	0.005 U	9E-04
Barium	0.022		0.01	0.022	0.023	0.007	0.008	0.008	0.08	0.015
Beryllium	0.001 U	5E-04 U	0 U	0.0005 U	5E-04 U	0.0005 U	0.0005 U	0.0005 U	5E-04 U	5E-04
Cadmium	0.001 U		0 U	0.001 U	5E-04 U	0.001 U	0.001 U	0.001 U	0.001 U	5E-04
Calcium					12					
Chromium	0.003		0 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.002
Copper					0.02 U					
Iron					0.05 U					
Lead					5E-04 U					
Magnesium					4.7					
Manganese					0.055					
Mercury	0.0005 U		0 U	0.0005 U	5E-04 U	0.0005 U	0.0005 U	0.0005 U	5E-04 U	5E-04
Nickel	0.05 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01
Selenium	0.005 U		0.01 U	0.005 U	0.001	0.005 U	0.005 U	0.005 U	0.005 U	5E-04 U
Silver					5E-04 U					
Sodium	28		31	32	31	29	21	35	33	39
Thallium	0.002 U	0.002 U	0 U	0.002 U	5E-04 U	0.002 U	0.002 U	0.002 U	0.002 U	5E-04
Zinc					0.02 U					
General Chemical Parameters										
Cyanide, Total	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.005
Fluoride	0.2 U		0.2	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U

Notes:
Blank space indicates metal was not analyzed.
Concentrations are mg/L.
U = indicates chemical was not detected.

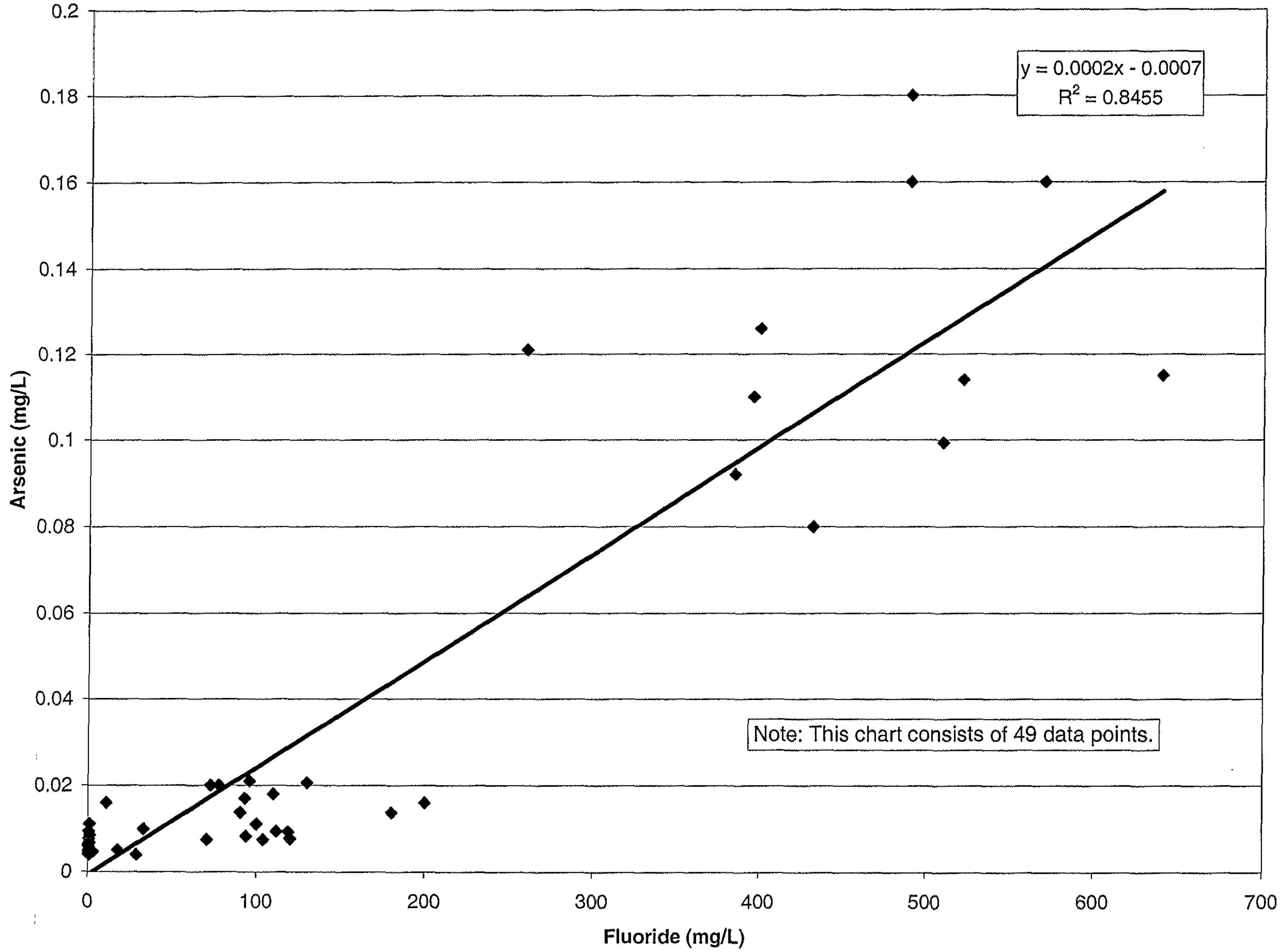

Figure B-1
ARSENIC VERSUS FLUORIDE CONCENTRATIONS DETECTED IN GROUNDWATER FROM THE RMC-TROUTDALE SITE
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment, Part 2--Groundwater

A scatter plot of iron versus fluoride concentrations detected in groundwater is presented in Figure B-2. The scatter plot results indicate that there is no correlation between iron and fluoride concentrations in groundwater; this is supported by the R^2 value of 0.2. The scatter plot shows one distinct location that is separate from the primary cluster of iron results. This data point, however, likely represents the results of a turbid sample, where the iron concentration is from suspended particulates rather than from soluble iron present in the water. A corresponding measure of soluble iron resulted in a concentration of less than 10 mg/L in this sample. The results of this scatter plot suggest that iron concentrations in groundwater are at naturally occurring levels, and are not the result of site co-releases with fluoride. As requested by EPA, however, iron was carried forward to the Tier 2 RA.

A scatter plot of manganese versus fluoride concentrations detected in groundwater is presented in Figure B-3. The scatter plot results indicate that there is no correlation between manganese and fluoride concentrations in groundwater; this is supported by the R^2 value of 0.1. The scatter plot shows one distinct location with a relatively high manganese concentration (greater than 7 mg/L) and a corresponding high fluoride concentration. This data point, however, represents the results of a turbid sample, where the manganese concentration is from suspended particulates rather than from dissolved manganese present in the water. A corresponding measure of soluble manganese resulted in a concentration of less than 1 mg/L in this sample. The results of this scatter plot suggest that manganese concentrations in groundwater are at naturally occurring levels, and are not the result of site co-releases with fluoride. As requested by EPA, however, manganese was carried forward to the Tier 2 RA.

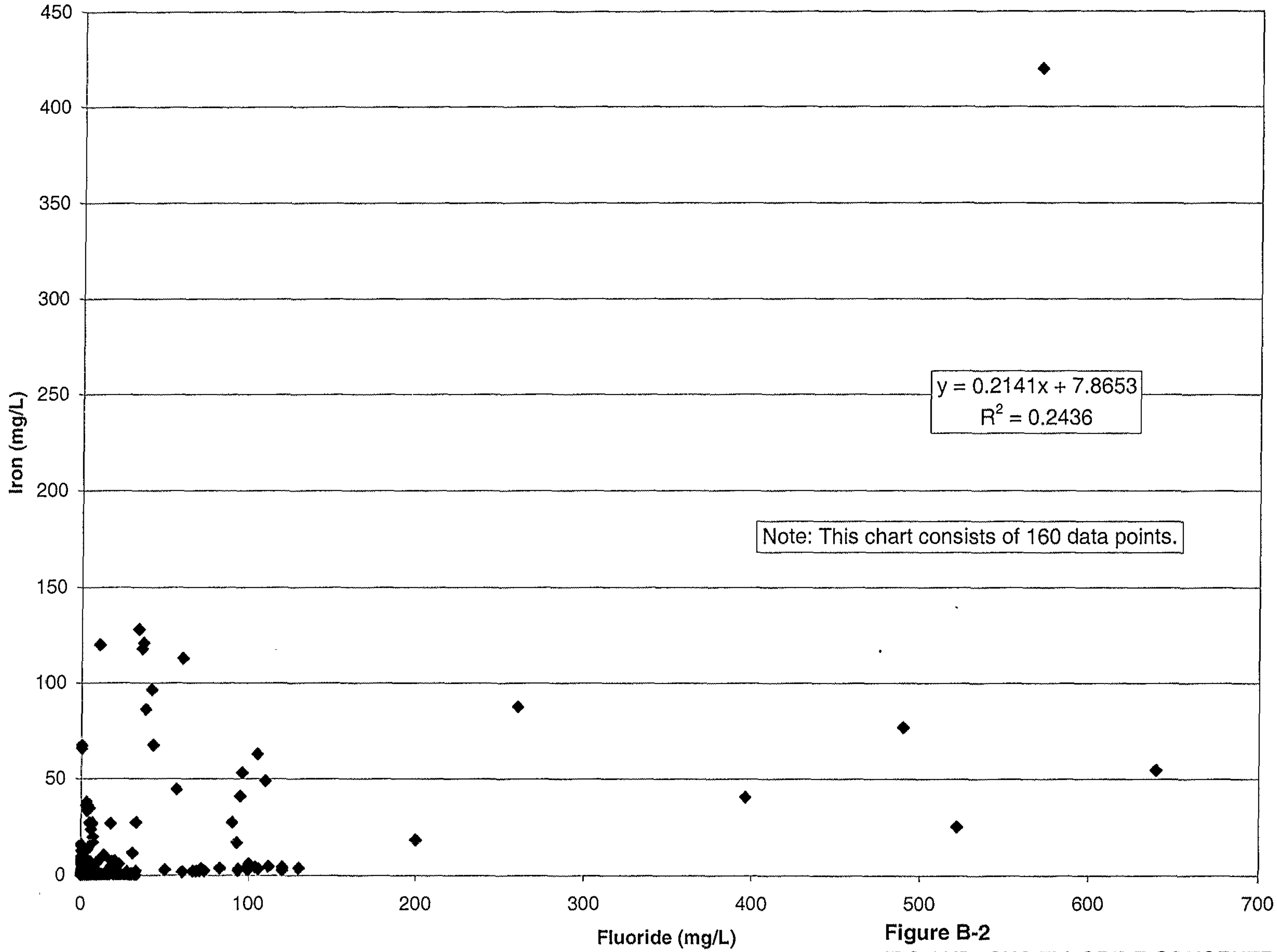

Figure B-2
IRON VERSUS FLUORIDE CONCENTRATIONS DETECTED IN GROUNDWATER FROM THE RMC-TROUTDALE SITE
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment, Part 2--Groundwater

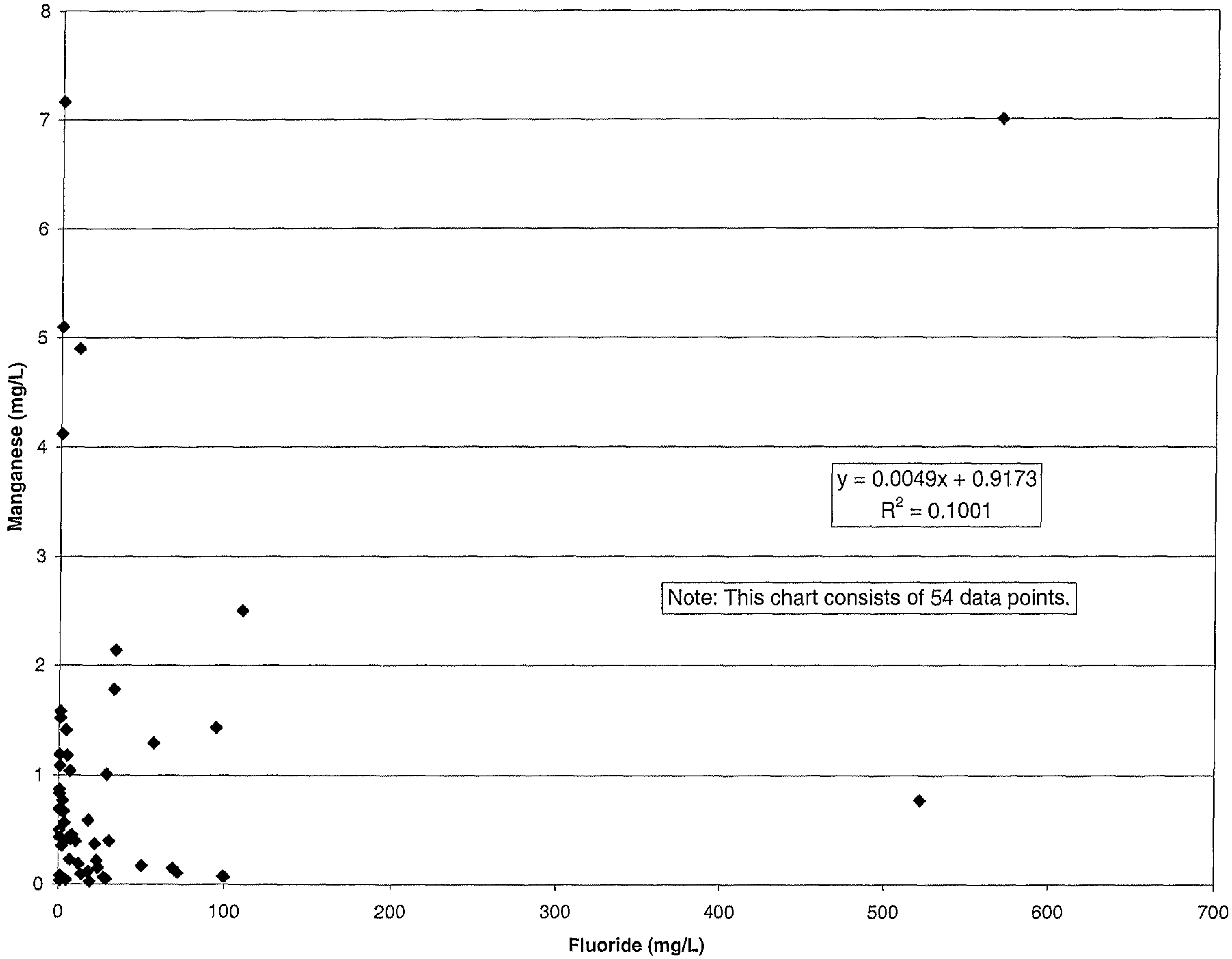

Figure B-3
MANGANESE VERSUS FLUORIDE CONCENTRATIONS DETECTED IN GROUNDWATER FROM THE RMC-TROUTDALE SITE
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment, Part 2--Groundwater

APPENDIX C

Estimating Exposure Concentrations at Fairview Farms

Contents of Appendix C

APPENDIX C

Estimating Exposure Concentrations at Fairview Farms

The fluoride exposure concentrations for the occupational and residential exposure scenarios at Fairview Farms were estimated using the site-scale groundwater flow model (CH2M HILL, 1999c) and the existing distribution of fluoride in groundwater (CH2M HILL, 1999b). Separate simulations were performed for the occupational and residential scenarios. For each scenario, the fluoride exposure concentration was estimated by simulating pumping from a single well located in the portion of Fairview Farms where fluoride concentrations are highest in order to estimate the greatest exposure potential that could occur within the Fairview Farms property.

Fluoride is generally absent in groundwater beneath and immediately east of the Fairview Farms property (CH2M HILL, 1999b). Fluoride has not been detected above the maximum contaminant level (MCL) in the overlying upper gray sand (UGS) zone or the underlying deep aquifer zone in this general area. However, fluoride is present above the MCL in intermediate-zone groundwater beneath the northeastern corner of the property. The presence of fluoride in the intermediate zone is attributed to leakage from Company Lake into underlying groundwater (CH2M HILL, 1999b).

Fluoride has been detected in the intermediate zone at two monitoring wells (MW06-094 and MW31-095) where sampling has been conducted since November 1996 and February 1997, respectively. Fluoride concentrations ranged from 13 to 16 milligrams per liter (mg/L) at location MW06-094 and from 6.58 to 24 mg/L at MW31-095. Fluoride was also detected at a temporary Geoprobe® sampling location (GP45), where samples were collected during August 1997. The highest fluoride concentration (20.5 mg/L) in the intermediate zone was measured at GP45 at a depth of 82 feet below the ground surface (bgs). Figure C-1 shows the spatial distribution of fluoride in the intermediate zone.

For each of the two scenarios (occupational and residential), the site-scale groundwater flow model was used to estimate the fluoride exposure concentration by simulating the pumping rate specific to the use scenario and by comparing the simulated capture zone of the well with the existing concentration distribution of fluoride in groundwater. Attachment A provides snapshot views, from the model, of the fluoride plumes and the hypothetical well's capture zone under the occupational exposure scenario. Attachment B provides snapshot views under the residential exposure scenario, including comparisons of the hypothetical well's capture zones for the occupational and residential exposure scenarios.

For each use scenario, the specific procedure for deriving the net in-well concentration of fluoride from the capture zone analysis and the fluoride concentration contours was as follows:

SRB COLOR50.DWG
27-JULY-1999

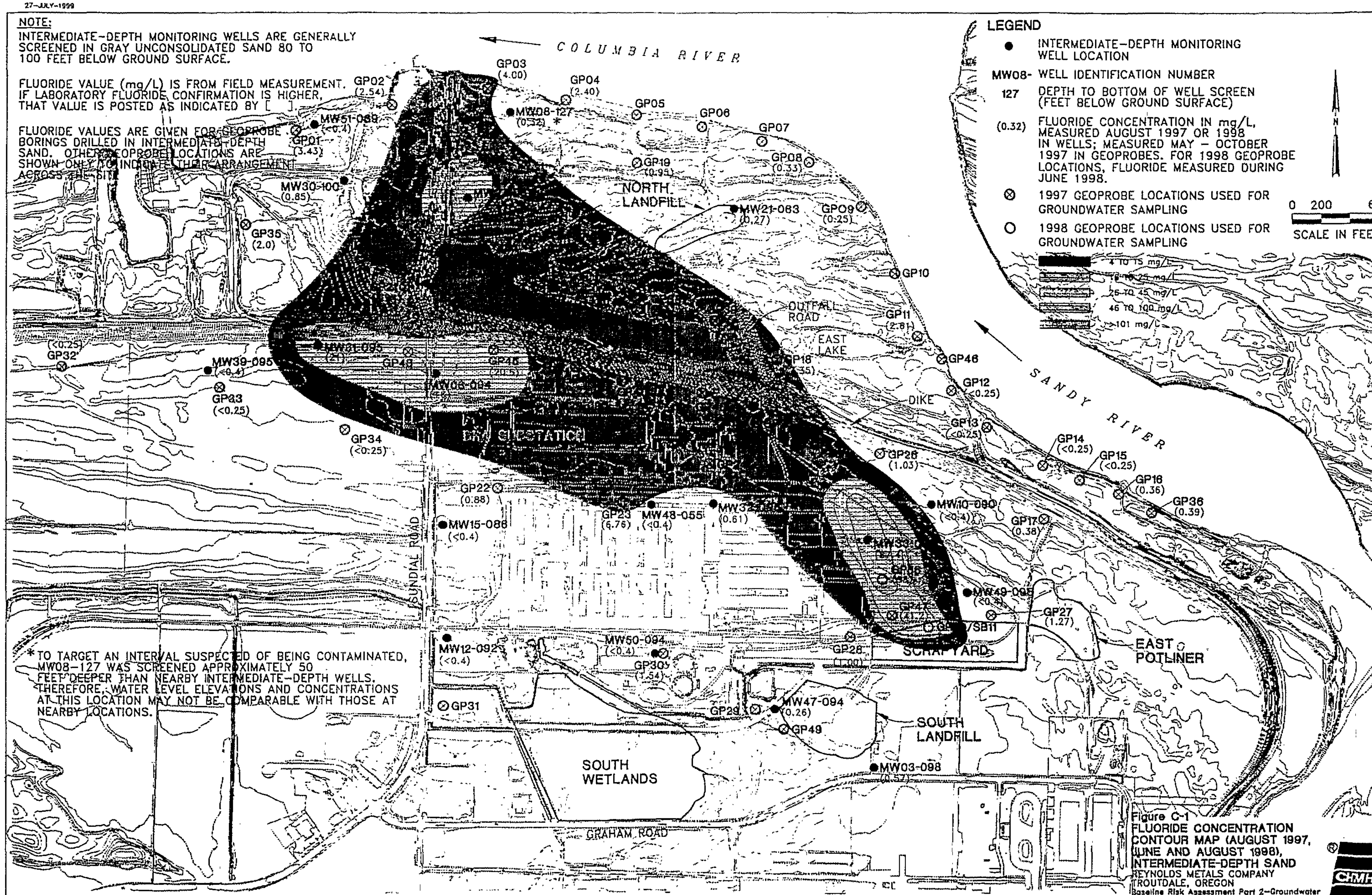

Figure C-1
FLUORIDE CONCENTRATION CONTOUR MAP (AUGUST 1997, JUNE AND AUGUST 1998), INTERMEDIATE-DEPTH SAND
REYNOLDS METALS COMPANY
TROUTDALE, OREGON
Baseline Risk Assessment Part 2-Groundwater

CH2MHILL

COLOR50.DWG

1. The hypothetical well was placed in the model in the northeastern corner of the Fairview Farms property and pumped at a rate consistent with the groundwater use scenario. RMC production well PW08 was also assumed to be in operation. Pumping was simulated as follows:

   - For the occupational exposure analysis, the hypothetical industrial well was pumped at a rate of 100 gpm from Layer 6 of the model (which occupies the depth interval from 100 to 150 feet bgs). The pumping rate is an estimated value corresponding to a well that could support light industrial activities. This rate is lower than the capacities of the RMC production wells (between 400 and 1,000 gpm) and the nearby Troutdale Airport well (800 gpm), which results in a conservative (higher) estimate of concentration. The selected depth interval is the same as for a nearby industrial well owned by Gresham Sand & Gravel, which is screened over the depth interval 120 to 130 feet bgs.

   - For the residential exposure analysis, the hypothetical domestic well was pumped at a rate of 5 gpm from Layer 5 of the model (which occupies the depth interval from 75 to 100 feet bgs). The pumping rate is an estimated value corresponding to the instantaneous yield of a domestic water supply well. The hypothetical well was screened at the same depth as the highest detected fluoride concentration beneath the Fairview Farms property. This screen depth was also one model layer higher (25 feet higher) than the depth of the well that was simulated for the occupational exposure analysis. The residential well was modeled as being shallower than the industrial well because of its substantially lower pumping rate (5 gpm, versus 100 gpm for the industrial well). Although a domestic well could conceivably be screened at an even shallower depth than was simulated with the model, the use of a shallower depth would have potentially caused an underestimation of the worst-case exposure concentration because fluoride concentrations are lower in the portions of the aquifer represented by Layers 1 through 4 of the model.

   - For both simulations, PW08 was pumped at a rate of 600 gallons per minute (gpm), based on historical pumping patterns under plant operating conditions. Pumping was simulated from Layers 7 and 9 of the 11-layer flow model, based on the actual depths of the open intervals of the well. (Layer 7 occupies the depth interval from 150 to 200 bgs. Layer 9 occupies the depth interval from 230 to 260 feet bgs.)

2. The model was run with the simulated pumping rate for the particular groundwater use scenario in order to calculate steady-state groundwater elevations in all model layers throughout the model domain (which extends approximately 2 miles to the west and 3 miles to the east of the hypothetical well).

3. Three-dimensional particle tracking was then performed to delineate a 25-year capture zone for the hypothetical well. The 25-year period was selected because it corresponds to the duration of the exposure that is the basis for the calculation of baseline risk. Particle tracking was conducted by initiating particles around the circumference of the well's open interval at multiple depths within the model layer where pumping was simulated from the well. A total of 2,000 particles were traced backward for a 25-year period based on the placement of 20 particles at each of 100 uniform depth intervals within the pumping layer.

4. The three-dimensional traces of each of the 2,000 particles were compared with the current fluoride distribution. For each particle trace, concentrations and associated travel times were assigned to each portion of the particle trace that lay in different model layers. The assignment of concentrations incorporated the following considerations:

   - For the occupational exposure scenario, particles that passed through the intermediate zone (model Layers 4 and 5) before migrating into the underlying pumping layer (Layer 6) were assigned intermediate-zone concentrations along the portion of the traces situated in the deep zone. This assignment was made despite the fact that fluoride is not currently present in deep-zone groundwater at the location of the hypothetical industrial well. This assignment is based on the shape of the capture zone, which indicates that the pumping of the hypothetical industrial well would cause fluoride migration from the intermediate zone to be captured by the well, thereby causing deep-zone concentrations to increase in close proximity to the well.
   - For the occupational exposure scenario, some particles were not traced upward into the intermediate zone. For these particles, intermediate-zone concentrations were not assigned along any portion of the flow path.
   - For particles traced back to Company Lake, travel times from Company Lake to the well were defined from the time that the particle entered the intermediate zone from the overlying UGS. This assignment was made because Company Lake partially penetrates the UGS. This assignment applied to both the occupational and the residential exposure analyses.
   - For both the occupational and the residential exposure analyses, particles that were traced into the UGS near the Company Lake shoreline were assigned concentrations equal to the intermediate-zone concentrations. This assignment was made because the locations of the UGS and intermediate-zone monitoring wells are such that the intermediate-zone wells are more representative of the effects of fluoride leaching through the bed of Company Lake than the UGS monitoring wells. This is because of the strong downward migration of fluoride in groundwater directly beneath the bed of Company Lake (CH2M HILL, 1996b).

5. The concentration and travel time data for each of the 2,000 traces were then used to calculate the arithmetic mean concentration along the entire length of each trace. The net concentration in the well was then calculated as the arithmetic mean of the concentrations for all 2,000 traces.

Using the procedures above, the net average concentrations of fluoride over a 25-year period in the Fairview Farms hypothetical well were calculated to be 5.8 mg/L for the occupational exposure scenario and 7.1 mg/L for the residential exposure scenario. A summary of these exposure concentrations and the differences between the occupational and residential exposure analyses is presented in Table C-1. These exposure concentrations provide conservative high-end estimates of potential exposure concentrations for the following reasons:

- The hypothetical well is simulated at a geographic location that coincides with the highest current fluoride concentrations observed southwest of Company Lake. In addition, the model runs were examined to ensure that the placement of the well allowed for continued capture of the elevated fluoride concentrations situated between Company Lake and the Fairview Farms property.

- The simulated depth of the hypothetical well was selected to ensure that the well captures the highest fluoride concentrations present beneath Fairview Farms.
- The modeling analysis simulates pumping (and therefore exposure) as a steady-state, long-term event, rather than simulating intermittent periods of pumping and exposure.

Nonfluoride Constituents

For nonfluoride constituents identified during Tier 1 for evaluation during Tier 2, an evaluation was conducted to determine whether elevated site groundwater concentrations were located within the capture zone of the Fairview Farms hypothetical well under either the occupational or the residential use scenarios. The model simulations described above were used to evaluate whether the capture zones for the hypothetical well under the occupational and residential use scenarios include any of the well locations where elevated concentrations were present. The following list summarizes the locations where Tier 1 constituents were detected at concentrations exceeding drinking water standards:

- Arsenic was detected at location MW11-017 at a concentration exceeding the MCL of 0.05 mg/L.
- Cyanide was detected at MW33-165 and MW34-038 at concentrations exceeding the MCL of 0.2 mg/L.
- Iron was detected in MW04-019, MW10-090, MW12-021, MW15-086, MW17-028, MW18-016, MW21-012, MW21-063, MW30-100, MW37-012, MW37-030, MW38-035, MW50-094, MW51-069, and MW53-034 at concentrations exceeding the secondary MCL of 0.3 mg/L (some background wells also exceed the MCL).
- Manganese was detected in MW18-031, MW37-030, and MW50-094 at concentrations exceeding the secondary MCL of 0.05 mg/L (some background wells also exceed the MCL).
- PCE was detected in MW32-040 at a concentration exceeding the MCL of 0.005 mg/L.

The capture zone analyses indicated that none of the well locations with concentrations exceeding drinking water standards lie within the capture zones for the hypothetical well under either the occupational or the residential exposure scenario. Therefore, nonfluoride constituents were not included in the risk analysis calculations for the Fairview Farms hypothetical well under the two exposure scenarios.

Table C-1
Comparison of Fluoride Concentrations for Occupational and Residential Exposure: Future Use Scenario at Fairview Farms

Exposure Scenario	Pumping Rate (gpm)	Depth (feet)	Aquifer Zone (Model Layer)	Net In-Well Concentration (mg/L)	In-Well Mixing Factor
Occupational	100	100-150	Deep (6)	5.8	3.6
Residential	5	75-100	Intermediate (5)	7.1	2.8

Note: In-well mixing factor is calculated as 20 mg/L divided by the net in-well concentration of fluoride.

APPENDIX D

Toxicological Profile for Fluoride

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APPENDIX D
Toxicological Profile for Fluoride

The adverse health effects from exposure to fluoride are dependent on its chemical form, route of exposure, duration, and dose. Fluoride can exist in several chemical forms, including fluorine (a gas), hydrogen fluoride (a gas), salts (sodium and calcium), cryolite (a mineral containing sodium, fluoride, and aluminum), and hydrofluoric acid (a liquid). Fluorine gas reacts very quickly with soil constituents, forming fluoride salts. Hydrogen fluoride dissolves readily in any water present in the air or other media, forming hydrofluoric acid. In dilute solutions, hydrofluoric acid is almost completely ionized and will form salts if cations are available. Calcium fluoride is much less soluble than sodium fluoride.

The primary exposure routes and duration of concern vary with the chemical form of fluoride. In general, oral absorption and toxicity increase with increased solubility. Inhalation and dermal contact are the primary exposure routes for hydrofluoric acid and are primarily associated with acute occupational exposure. Chronic (long-term) ingestion of drinking water and food containing fluoride salts (often as sodium fluoride) is the primary exposure route associated with the general public.

Acute Noncancer Effects

Oral intake of large amounts of sodium fluoride can cause stomachaches, vomiting, and diarrhea. If extremely large amounts are consumed, death can result from damage to the stomach and the heart.

Inhalation exposure most commonly occurs in occupational settings. Inhalation of fluorine gas causes nasal and eye irritation (at low levels) and death from pulmonary edema (at high levels). Fluorine gas is extremely irritating to the respiratory tract. Inhalation of hydrogen fluoride can cause bronchiolar ulceration, pulmonary hemorrhage and edema, and death.

Dermal exposure to concentrated hydrofluoric acid can burn the eyes and skin. If they are not treated properly, serious skin damage and tissue loss can occur. A large amount of hydrofluoric acid on the skin can cause lethal damage to the lungs and heart.

Chronic Noncancer Effects

Chronic exposure (by inhalation or oral ingestion) to large amounts of fluoride-containing dust or water (usually in the form of hydrogen fluoride, cryolite, or sodium fluoride) can damage the bones and teeth, resulting in skeletal or dental fluorosis. Skeletal fluorosis involves denser bones, joint pain, and limited range of motion. Severe cases may result in a completely rigid spine. Despite increased bone density, people suffering from skeletal fluorosis have weaker bones that break more easily than normal bone. Dental fluorosis results in teeth mottling. Milder exposures cause only cosmetic effects involving small white spots on the teeth. In moderate cases, there are large white spots and some brown spots. In severe cases, the teeth become pitted, have many brown stains, may become more fragile, and sometimes develop more cavities.

It is not known whether fluoride affects reproduction in people. Some laboratory animal experiments have found reproductive effects of fluoride, while others have not. The significance of these results to human health is not clear. It is also not known whether fluoride causes birth defects in people or animals. No researchers have studied developmental effects of fluoride using standard testing methods.

The oral reference dose (RfD) for fluoride is 0.06 mg/kg-day with dental fluorosis (a cosmetic effect) as the endpoint. Because this is derived from a study on children, no modifying or uncertainty factors were applied to the no observed adverse effect level (NOAEL).

Carcinogenicity

Well-designed epidemiological studies to determine whether fluoride causes cancer in people have generally not found any association between fluoride and cancer. A large study of fluoride effects on both rats and mice found that a small number of male rats developed bone cancer after drinking water with high levels of fluoride [25-175 parts per million (ppm)] throughout their lives. This is considered equivocal evidence that fluoride causes cancer in male rats. Fluoride did not cause cancer in mice or female rats. Another study found no evidence that fluoride causes cancer in rats. Both animal studies had problems that limited their usefulness in showing whether or not fluoride can cause cancer in humans. The International Agency for Research on Cancer (IARC) reviewed the literature on fluoride carcinogenicity in 1982. It concluded that there is no evidence from epidemiological studies of an association between fluoride ingestion and human cancer mortality, and that the available data are inadequate for an evaluation of the carcinogenicity of sodium fluoride in laboratory animals.

Fluoride in Drinking Water

Fluoride is naturally present in many sources of drinking water. Most drinking water contains less than 1 ppm fluoride. In some parts of the world (where skeletal fluorosis is endemic), drinking water fluoride concentrations may be as high as 20-40 ppm. Epidemiological studies have found that when drinking water contains more than 2 ppm fluorides, dental fluorosis is common, but the incidence of dental caries (cavities) is decreased. When drinking water contains about 1 ppm, mottling is not noted and cavities are reduced significantly. The maximum reduction of cavities occurs when drinking water contains 2-4 ppm fluoride. To prevent cavities, many U.S. cities add fluoride to drinking water to attain 1 ppm fluoride levels. Dental fluorosis occurs only from chronic exposure to drinking water containing > 1 ppm fluoride during the tooth formative period in children (from birth to age 9 years).

There is no scientific documentation of adverse medical effects at fluoride levels below 8 ppm in drinking water. No cases of crippling skeletal fluorosis have occurred with consumption of 2 liters/day drinking water containing 4 ppm fluoride. Crippling skeletal fluorosis has been observed in populations (not in the United States) chronically exposed to consumption of 2 liters/day drinking water containing 4 ppm fluoride. Crippling skeletal fluorosis has been observed in populations (not in the United States) chronically exposed to fluoride in drinking water at levels of 10 to 40 ppm. This condition is very rare in the United States even though some communities have similar drinking water fluoride concentrations. This inconsistency between fluoride dose and effect has been attributed to unidentified metabolic factors or malnutrition in populations with high incidences of crippling skeletal fluorosis.

Because fluoride increases bone density, it has been studied as a possible treatment for osteoporosis. A number of studies have shown increased bone density with 0.93 to 17 ppm drinking water fluoride concentrations. However, most of these studies have also shown an increase in bone fractures with fluoride treatment.

The EPA secondary maximum contaminant level (SMCL) for drinking water is 2 ppm. The EPA recommended maximum contaminant level (RMCL) is 4 ppm. At 4 ppm it is estimated that about 90 percent of permanent residents would exhibit some degree of dental fluorosis, about half of those would be moderate to severe cases, and a small number of people would have increased bone density. EPA considers dental fluorosis a cosmetic, not an adverse, effect. EPA does, however, consider the crippling skeletal fluorosis occurring at higher exposures an adverse health effect.

References

ATSDR Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine. April 1993.

Underwood, Eric J. 1977. Fluorine. Trace Elements in Human and Animal Nutrition, 4th edition. Academic Press. Pages 358-359.

U.S. Environmental Protection Agency. 1985. Federal Register Vol. 50, 20164, 47142.

______________. 1998. Integrated Risk Information System (IRIS) database. EPA online toxicity database. Office of Research and Development, Cincinnati, Ohio. Profile on Fluorine. October 1998.

APPENDIX E

Tier 2 Risk Assessment Results

Contents of Appendix E

Tables

Table E-1
NONCANCER HEALTH RISK EVALUATION
Current Onsite Exposure
Ingestion of Groundwater

Chemical	Reference Dose (RfD) (mg/kg-day)	Occupational Worker		
		Exposure Point Concentration (mg/L)	Estimated Intake (DI) (mg/kg-day)	Hazard Quotient (DI/RfD)
Cyanide	2.00E-02	2.54E-02	2.49E-04	1.2E-02
Fluoride	6.00E-02	1.51E+00	1.48E-02	2.5E-01
HAZARD INDEX (Sum of DI/RfD)				**0.259**

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Groundwater Ingestion Rate (L/day)	1
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time (yr)	25

Table E-2
EXCESS LIFETIME CANCER RISK
Current Onsite Exposure
Ingestion of Groundwater

Chemical	EPA Carcinogen Classification	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Occupational Worker		
			Exposure Point Concentration (mg/L)	Lifetime Maximum Chemical Intake (mg/kg-day)	Excess Lifetime Cancer Risk
Cyanide	D	NA	2.54E-02	8.88E-05	NA
Fluoride	NA	NA	1.51E+00	5.28E-03	NA
SUM OF RISKS					**0.00E+00**

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Groundwater Ingestion Rate (L/day)	1
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time (yr)	70

Table E-3
NONCANCER HEALTH RISK EVALUATION
Current Onsite Exposure
Dermal Contact with Groundwater

Chemical	Reference Dose (RfD) (mg/kg-day)	Skin Permeability Constant	Occupational Worker: Exposure Point Concentration (mg/L)	Occupational Worker: Estimated Intake (DI) (mg/kg-day)	Occupational Worker: Hazard Quotient (DI/RfD)
Cyanide	2.00E-02	1.00E-03	2.54E-02	1.12E-06	5.59E-05
Fluoride	6.00E-02	1.00E-03	1.51E+00	6.65E-05	1.11E-03
HAZARD INDEX (Sum of DI/RfD)					**0.001**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Skin Surface Area (cm^2)					18,000
Exposure Time (hr/day)					0.25
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					25

Table E-4
EXCESS LIFETIME CANCER RISK
Current Onsite Exposure
Dermal Contact with Groundwater

Chemical	EPA Carcinogen Classification	Skin Permeability Constant	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Occupational Worker: Exposure Point Concentration (mg/L)	Occupational Worker: Lifetime Maximum Chemical Intake (mg/kg-day)	Occupational Worker: Excess Lifetime Cancer Risk
Cyanide	D	1.00E-03	NA	2.54E-02	3.99E-07	NA
Fluoride	NA	1.00E-03	NA	1.51E+00	2.37E-05	NA
SUM OF RISKS						**0.00E+00**
EXPOSURE ASSUMPTIONS						
Exposure Setting						Occupational Worker
Exposure Case						Reasonable Maximum
Skin Surface Area (cm^2)						18,000
Exposure Time (hr/day)						0.25
Body Weight (kg)						70
Number of Days/Year Exposed						250
Number of Years Exposed						25
Averaging Time (yr)						70

Table E-5
NONCANCER HEALTH RISK EVALUATION
Current Onsite Exposure
Inhalation of VOCs in Groundwater

Chemical	Inhalation Reference Dose (mg/kg-day)	Volatilization factor-k (L/m^3)	Occupational Worker Exposure Point Concentration (mg/L)	Occupational Worker Estimated Intake (DI) (mg/kg-day)	Occupational Worker Hazard Quotient (DI/RfD)
Cyanide	NA	0.50	2.54E-02	2.49E-03	NA
Fluoride	NA	0.50	1.51E+00	1.48E-01	NA
HAZARD INDEX (Sum of DI/RfD)					**0.00E+00**

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Inhalation Rate (m^3/day)	20
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time (yr)	25

Table E-6
EXCESS LIFETIME CANCER RISK
Current Onsite Exposure
Inhalation of VOCs in Groundwater

Chemical	EPA Carcinogen Classification	Volatilization factor-k (L/m^3)	Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Occupational Worker Exposure Point Concentration (mg/L)	Occupational Worker Lifetime Maximum Chemical Intake (mg/kg-day)	Occupational Worker Excess Lifetime Cancer Risk
Cyanide	D	0.50	NA	2.54E-02	8.88E-04	NA
Fluoride	NA	0.50	NA	1.51E+00	5.28E-02	NA
SUM OF RISKS						**0.00E+00**

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Inhalation Rate (m^3/day)	20
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time (yr)	70

Table E-7
AGGREGATE RISK ESTIMATES
Current Onsite Exposure
Groundwater

Chemical	OCCUPATIONAL WORKER				% of
	INGESTION	DERMAL	INHALATION	SUM	Total ELCR
Cyanide	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA
SUM OF RISKS	**0.0E+00**	**0.0E+00**	**0.0E+00**	**0.00E+00**	

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Groundwater Ingestion Rate (L/day)	1
Inhalation Rate (m^3/day)	20
Skin Surface Area (cm^2)	18,000
Exposure Time (hr/day)	0.25
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time - Cancer (yr)	70

Table E-8
AGGREGATE HAZARD ESTIMATES
Current Onsite Exposure
Groundwater

Chemical	OCCUPATIONAL WORKER				% of
	INGESTION	DERMAL	INHALATION	SUM	Total HI
Cyanide	1.2E-02	5.6E-05	NA	1.25E-02	4.8%
Fluoride	2.5E-01	1.1E-03	NA	2.47E-01	95.2%
SUM OF RISKS	**2.59E-01**	**1.16E-03**	**0.00E+00**	**2.60E-01**	

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Groundwater Ingestion Rate (L/day)	1
Inhalation Rate (m^3/day)	20
Skin Surface Area (cm^2)	18,000
Exposure Time (hr/day)	0.25
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time - Noncancer (yr)	25

Table E-9 NONCANCER HEALTH RISK EVALUATION Future Onsite Exposure Ingestion of Groundwater				
		Occupational Worker		
Chemical	Reference Dose (RfD) (mg/kg-day)	Exposure Point Concentration (mg/L)	Estimated Intake (DI) (mg/kg-day)	Hazard Quotient (DI/RfD)
1,1-dichloroethene	9.00E-03	4.90E-05	4.79E-07	5.3E-05
Cyanide	2.00E-02	2.20E-02	2.15E-04	1.1E-02
Fluoride	6.00E-02	1.99E+00	1.95E-02	3.2E-01
Tetrachloroethene	1.00E-02	4.20E-03	4.11E-05	4.1E-03
HAZARD INDEX (Sum of DI/RfD)				**3.39E-01**
EXPOSURE ASSUMPTIONS				
Exposure Setting				Occupational Worker
Exposure Case				Reasonable Maximum
Groundwater Ingestion Rate (L/day)				1
Body Weight (kg)				70
Number of Days/Year Exposed				250
Number of Years Exposed				25
Averaging Time (yr)				25

Table E-10 EXCESS LIFETIME CANCER RISK Future Onsite Exposure Ingestion of Groundwater					
			Occupational Worker		
Chemical	EPA Carcinogen Classification	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Exposure Point Concentration (mg/L)	Lifetime Maximum Chemical Intake (mg/kg-day)	Excess Lifetime Cancer Risk
1,1-dichloroethene	C	6.00E-01	4.90E-05	1.71E-07	1.03E-07
Cyanide	D	NA	2.20E-02	7.69E-05	NA
Fluoride	NA	NA	1.99E+00	6.95E-03	NA
Tetrachloroethene	C/B2	5.10E-02	4.20E-03	1.47E-05	7.49E-07
SUM OF RISKS					**8.51E-07**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Groundwater Ingestion Rate (L/day)					1
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					70

Table E-11 NONCANCER HEALTH RISK EVALUATION Future Onsite Exposure Dermal Contact with Groundwater					
			Occupational Worker		
Chemical	Reference Dose (RfD) (mg/kg-day)	Skin Permeability Constant	Exposure Point Concentration (mg/L)	Estimated Intake (DI) (mg/kg-day)	Hazard Quotient (DI/RfD)
1,1-dichloroethene	9.00E-03	1.60E-02	4.90E-05	3.45E-08	3.8E-06
Cyanide	2.00E-02	1.00E-03	2.20E-02	9.69E-07	4.8E-05
Fluoride	6.00E-02	1.00E-03	1.99E+00	8.76E-05	1.5E-03
Tetrachloroethene	1.00E-02	4.80E-02	4.20E-03	8.88E-06	8.9E-04
HAZARD INDEX (Sum of DI/RfD)					**2.40E-03**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Skin Surface Area (cm^2)					18,000
Exposure Time (hr/day)					0.25
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					25

Table E-12 EXCESS LIFETIME CANCER RISK Future Onsite Exposure Dermal Contact with Groundwater						
				Occupational Worker		
Chemical	EPA Carcinogen Classification	Skin Permeability Constant	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Exposure Point Concentration (mg/L)	Lifetime Maximum Chemical Intake (mg/kg-day)	Excess Lifetime Cancer Risk
1,1-dichloroethene	C	1.60E-02	6.00E-01	4.90E-05	1.23E-08	7.40E-09
Cyanide	D	1.00E-03	NA	2.20E-02	3.46E-07	NA
Fluoride	NA	1.00E-03	NA	1.99E+00	3.13E-05	NA
Tetrachloroethene	C/B2	4.80E-02	5.10E-02	4.20E-03	3.17E-06	1.62E-07
SUM OF RISKS						**1.69E-07**
EXPOSURE ASSUMPTIONS						
Exposure Setting						Occupational Worker
Exposure Case						Reasonable Maximum
Skin Surface Area (cm^2)						18,000
Exposure Time (hr/day)						0.25
Body Weight (kg)						70
Number of Days/Year Exposed						250
Number of Years Exposed						25
Averaging Time (yr)						70

Table E-13 NONCANCER HEALTH RISK EVALUATION Future Onsite Exposure Inhalation of VOCs in Groundwater					
			Occupational Worker		
Chemical	**Inhalation Reference Dose (mg/kg-day)**	**Volatilization factor-k (L/m^3)**	**Exposure Point Concentration (mg/L)**	**Estimated Intake (DI) (mg/kg-day)**	**Hazard Quotient (DI/RfD)**
1,1-dichloroethene	NA	1.50	4.90E-05	1.44E-05	NA
Cyanide	NA	3.50	2.20E-02	1.51E-02	NA
Fluoride	NA	4.50	1.99E+00	1.75E+00	NA
Tetrachloroethene	NA	7.50	4.20E-03	6.16E-03	NA
HAZARD INDEX (Sum of DI/RfD)					**0.000**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Inhalation Rate (m^3/day)					20
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					25

Table E-14 EXCESS LIFETIME CANCER RISK Future Onsite Exposure Inhalation of VOCs in Groundwater						
				Occupational Worker		
Chemical	**EPA Carcinogen Classification**	**Volatilization factor-k (L/m^3)**	**Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$**	**Exposure Point Concentration (mg/L)**	**Lifetime Maximum Chemical Intake (mg/kg-day)**	**Excess Lifetime Cancer Risk**
1,1-dichloroethene	C	1.50	1.75E-01	4.90E-05	5.14E-06	8.99E-07
Cyanide	D	3.50	NA	2.20E-02	5.38E-03	NA
Fluoride	NA	4.50	NA	1.99E+00	6.26E-01	NA
Tetrachloroethene	C/B2	7.50	2.03E-03	4.20E-03	2.20E-03	4.47E-06
SUM OF RISKS						**5.37E-06**
EXPOSURE ASSUMPTIONS						
Exposure Setting						Occupational Worker
Exposure Case						Reasonable Maximum
Inhalation Rate (m^3/day)						20
Body Weight (kg)						70
Number of Days/Year Exposed						250
Number of Years Exposed						25
Averaging Time (yr)						70

Table E-15 AGGREGATE RISK ESTIMATES Future Onsite Exposure Groundwater					
	OCCUPATIONAL WORKER				% of
Chemical	INGESTION	DERMAL	INHALATION	SUM	Total ELCR
1,1-dichloroethene	1.03E-07	7.40E-09	8.99E-07	1.01E-06	15.8
Cyanide	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA
Tetrachloroethene	7.49E-07	1.62E-07	4.47E-06	5.38E-06	84.2
SUM OF RISKS	**8.5E-07**	**1.7E-07**	**5.4E-06**	**6.4E-06**	
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Groundwater Ingestion Rate (L/day)					1
Inhalation Rate (m^3/day)					20
Skin Surface Area (cm^2)					18,000
Exposure Time (hr/day)					0.25
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time - Cancer (yr)					70

Table E-16 AGGREGATE HAZARD ESTIMATES Future Onsite Exposure Groundwater					
	OCCUPATIONAL WORKER				% of
Chemical	INGESTION	DERMAL	INHALATION	SUM	Total HI
1,1-dichloroethene	5.33E-05	3.84E-06	NA	5.71E-05	0.0%
Cyanide	1.08E-02	4.84E-05	NA	1.08E-02	3.2%
Fluoride	3.25E-01	1.46E-03	NA	3.26E-01	95.4%
Tetrachloroethene	4.11E-03	8.88E-04	NA	5.00E-03	1.5%
SUM OF RISKS	**3.39E-01**	**2.40E-03**	**0.00E+00**	**3.42E-01**	
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Inhalation Rate (m^3/day)					20
Groundwater Ingestion Rate (L/day)					1
Skin Surface Area (cm^2)					18,000
Exposure Time (hr/day)					0.25
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time - Noncancer (yr)					25

Table E-17 NONCANCER HEALTH RISK EVALUATION Current Offsite Exposure Ingestion of Groundwater				
		Occupational Worker		
Chemical	Reference Dose (RfD) (mg/kg-day)	Exposure Point Concentration (mg/L)	Estimated Intake (DI) (mg/kg-day)	Hazard Quotient (DI/RfD)
Fluoride	6.00E-02	3.50E-01	3.42E-03	5.7E-02
HAZARD INDEX (Sum of DI/RfD)				**5.71E-02**
EXPOSURE ASSUMPTIONS				
Exposure Setting				Occupational Worker
Exposure Case				Reasonable Maximum
Groundwater Ingestion Rate (L/day)				1
Body Weight (kg)				70
Number of Days/Year Exposed				250
Number of Years Exposed				25
Averaging Time (yr)				25

Table E-18 EXCESS LIFETIME CANCER RISK Current Offsite Exposure Ingestion of Groundwater					
			Occupational Worker		
Chemical	EPA *Carcinogen* Classification	Cancer *Slope Factor* (mg/kg-day)$^{-1}$	Exposure Point *Concentration* (mg/L)	Lifetime Maximum *Chemical Intake* (mg/kg-day)	Excess *Lifetime* Cancer Risk
Fluoride	NA	NA	3.50E-01	1.22E-03	NA
SUM OF RISKS					**0.00E+00**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Groundwater Ingestion Rate (L/day)					1
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					70

Table E-19 NONCANCER HEALTH RISK EVALUATION Current Offsite Exposure Dermal Contact with Groundwater					
			Occupational Worker		
Chemical	Reference Dose (RfD) (mg/kg-day)	Skin Permeability Constant	Exposure Point Concentration (mg/L)	Estimated Intake (DI) (mg/kg-day)	Hazard Quotient (DI/RfD)
Fluoride	6.00E-02	1.00E-03	3.50E-01	1.54E-05	2.6E-04
HAZARD INDEX (Sum of DI/RfD)					**2.57E-04**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Exposure Case					Reasonable Maximum
Skin Surface Area (cm^2)					18,000
Exposure Time (hr/day)					0.25
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					25

Table E-20 EXCESS LIFETIME CANCER RISK Current Offsite Exposure Dermal Contact with Groundwater						
				Occupational Worker		
Chemical	EPA Carcinogen Classification	Skin Permeability Constant	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Exposure Point Concentration (mg/L)	Lifetime Maximum Chemical Intake (mg/kg-day)	Excess Lifetime Cancer Risk
Fluoride	NA	1.00E-03	NA	3.50E-01	5.50E-06	NA
SUM OF RISKS						**0.00E+00**
EXPOSURE ASSUMPTIONS						
Exposure Setting						Occupational Worker
Exposure Case						Reasonable Maximum
Skin Surface Area (cm^2)						18,000
Exposure Time (hr/day)						0.25
Body Weight (kg)						70
Number of Days/Year Exposed						250
Number of Years Exposed						25
Averaging Time (yr)						70

Table E-21
NONCANCER HEALTH RISK EVALUATION
Current Offsite Exposure
Inhalation of VOCs in Groundwater

Chemical	Inhalation Reference Dose (mg/kg-day)	Volatilization factor-k (L/m^3)	Occupational Worker: Exposure Point Concentration (mg/L)	Occupational Worker: Estimated Intake (DI) (mg/kg-day)	Occupational Worker: Hazard Quotient (DI/RfD)
Fluoride	NA	0.50	3.50E-01	3.42E-02	NA
HAZARD INDEX (Sum of DI/RfD)					**0.000**
EXPOSURE ASSUMPTIONS					
Exposure Setting					Occupational Worker
Inhalation Rate (m^3/day)					20
Body Weight (kg)					70
Number of Days/Year Exposed					250
Number of Years Exposed					25
Averaging Time (yr)					25

Table E-22
EXCESS LIFETIME CANCER RISK
Current Offsite Exposure
Inhalation of VOCs in Groundwater

Chemical	EPA Carcinogen Classification	Volatilization factor-k (L/m^3)	Inhalation Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Occupational Worker: Exposure Point Concentration (mg/L)	Occupational Worker: Lifetime Maximum Chemical Intake (mg/kg-day)	Occupational Worker: Excess Lifetime Cancer Risk
Fluoride	NA	0.50	NA	3.50E-01	1.22E-02	NA
SUM OF RISKS						**0.00E+00**
EXPOSURE ASSUMPTIONS						
Exposure Setting						Occupational Worker
Exposure Case						Reasonable Maximum
Inhalation Rate (m^3/day)						20
Body Weight (kg)						70
Number of Days/Year Exposed						250
Number of Years Exposed						25
Averaging Time (yr)						70

Table E-23
AGGREGATE RISK ESTIMATES
Current Offsite Exposure
Groundwater

Chemical	OCCUPATIONAL WORKER				% of
	INGESTION	DERMAL	INHALATION	SUM	Total ELCR
Fluoride	NA	NA	NA	0.00E+00	NA
SUM OF RISKS	**0.0E+00**	**0.0E+00**	**0.0E+00**	**0.0E+00**	

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Groundwater Ingestion Rate (L/day)	1
Inhalation Rate (m^3/day)	20
Skin Surface Area (cm^2)	18,000
Exposure Time (hr/day)	0.25
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time - Cancer (yr)	70

Table E-24
AGGREGATE HAZARD ESTIMATES
Current Offsite Exposure
Groundwater

Chemical	OCCUPATIONAL WORKER				% of
	INGESTION	DERMAL	INHALATION	SUM	Total HI
Fluoride	5.71E-02	2.57E-04	NA	5.73E-02	100.0%
SUM OF RISKS	**5.71E-02**	**2.57E-04**	**0.00E+00**	**5.73E-02**	

EXPOSURE ASSUMPTIONS	
Exposure Setting	Occupational Worker
Exposure Case	Reasonable Maximum
Groundwater Ingestion Rate (L/day)	1
Skin Surface Area (cm^2)	18,000
Exposure Time (hr/day)	0.25
Body Weight (kg)	70
Number of Days/Year Exposed	250
Number of Years Exposed	25
Averaging Time - Noncancer (yr)	25